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CONTROL NO. C-63972

DATE 20 February 1962

REVISED 18 July 1962

GEMINI SPACECRAFT
PROPULSION
SYSTEMS SPECIFICATION

(TITLE UNCLASSIFIED)

REPORT 8642 SERIAL NO. 6

MCDONNELL AIRCRAFT CORPORATION

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REV

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NEW

1. GENERAL

1.1 SCOPE.- This specification describes the Propulsion Systems for the Gemini spacecraft (M.A.C. Model 133P) to be constructed by the McDonnell Aircraft Corporation (M.A.C.) for the National Aeronautics and Space Administration (NASA) under Contract NAS 9-170. The Propulsion Systems consist of an Orbit Attitude and Maneuver System, Retrograde Rocket System, and Re-Entry Control System. Included in this document is a definition of the function, operation, design requirements, and performance characteristics of the systems and their components, as well as the reliability and quality assurance test program to be performed to assure that these objectives are met. This document is not to be used for inspection purposes.

2. APPLICABLE DOCUMENTS

2.1 GENERAL.- It is the Contractor's intent, relevant to the use of government specifications in the design and administration of the Propulsion Systems, to utilize existing specifications where practicable. In cases where the subject matter is applicable but the specific requirements are not compatible due to the advanced design of these systems, the specifications and documents referenced are followed only to the extent that the intent of such requirements are met.

2.2 DOCUMENTS.- Government specifications, standards, and publications are listed in M.A.C. Report 8357.

2.2.1 CONTRACTOR PUBLICATIONS.- The following Contractor-prepared publications are applicable to this system specification.

M.A.C. Drawing 52-50700	Specification Control Drawing for Retrograde Rocket - Model 133P Capsule
M.A.C. Drawing 52-50702	Specification Control Drawing Retrograde Rocket - Gemini Spacecraft
M.A.C. Drawing 52-52700	Specification Control Drawing M.A.C. Model 133P Re-Entry Control System
M.A.C. Drawing 52-52701	Specification Control Drawing M.A.C. Model 133P Orbit Attitude and Maneuver System
M.A.C. Report 8580-3	Project Gemini Reliability Plan

2.2.1 CONTRACTOR PUBLICATIONS.- (Continued)

M.A.C. Report 8580-7	Quality Assurance Provisions (Plan) for Project Gemini Space System
M.A.C. Report 8580-8	Model 133P Gemini Program Documentation Plan
M.A.C. Report 8611	Gemini Spacecraft Performance Specification
M.A.C. Report 8637	Gemini Spacecraft Guidance and Control System Specification
M.A.C. Report 8757	Preservation, Packaging and Shipping of Gemini Parts and Equipments

REV

2.3 SUPERSEDENCE.- If any of the specifications, standards, drawings, and publications which form a part of this system specification are superseded during the life of the contract of which this system specification is a part, the later issue may be used.

3. ORBIT ATTITUDE AND MANEUVER SYSTEM

3.1 GENERAL.- The Orbit Attitude and Maneuver System (OAMS) is a liquid bipropellant rocket engine propulsion system consisting of sixteen fixed-mount Thrust Chamber Assemblies (TCA's) operating on storable hypergolic propellants supplied by a cold gas pressurized positive expulsion feed system. The sixteen TCA's are located in the adapter and are arranged as shown in Figure 1.

3.2 FUNCTION.- The OAMS, in conjunction with the Attitude Control and Maneuver Electronics (ACME), various sensing devices and the hand controllers and foot pedals, provides attitude and maneuver control of the spacecraft from the time of spacecraft separation from the launch vehicle until retrograde. At retrograde, the OAMS is jettisoned and spacecraft attitude control is provided by the Re-Entry Control System (RCS) from retrograde to deployment of the drogue chute or paraglider.

The OAMS is capable of two types of missions: a two day mission during which a rendezvous with the target vehicle (Agena) is carried out, or a fourteen day orbiting mission. The system responds to electrical signals from the Orbit Attitude and Maneuver Electronics (OAME) which is a part of the ACME. In response to the electrical signals, the OAMS produces rocket thrust forces for attitude control and maneuver of the spacecraft. REV

Translation of the spacecraft is controlled by the crew through use of the maneuver hand controller. Attitude is controlled automatically by the ACME or manually by the crew through the ACME. Control by the crew in pitch and roll is accomplished with the attitude hand controller and in yaw with the foot pedals (a detailed discussion of the guidance and control modes of operation is contained in M.A.C. Report 8637).

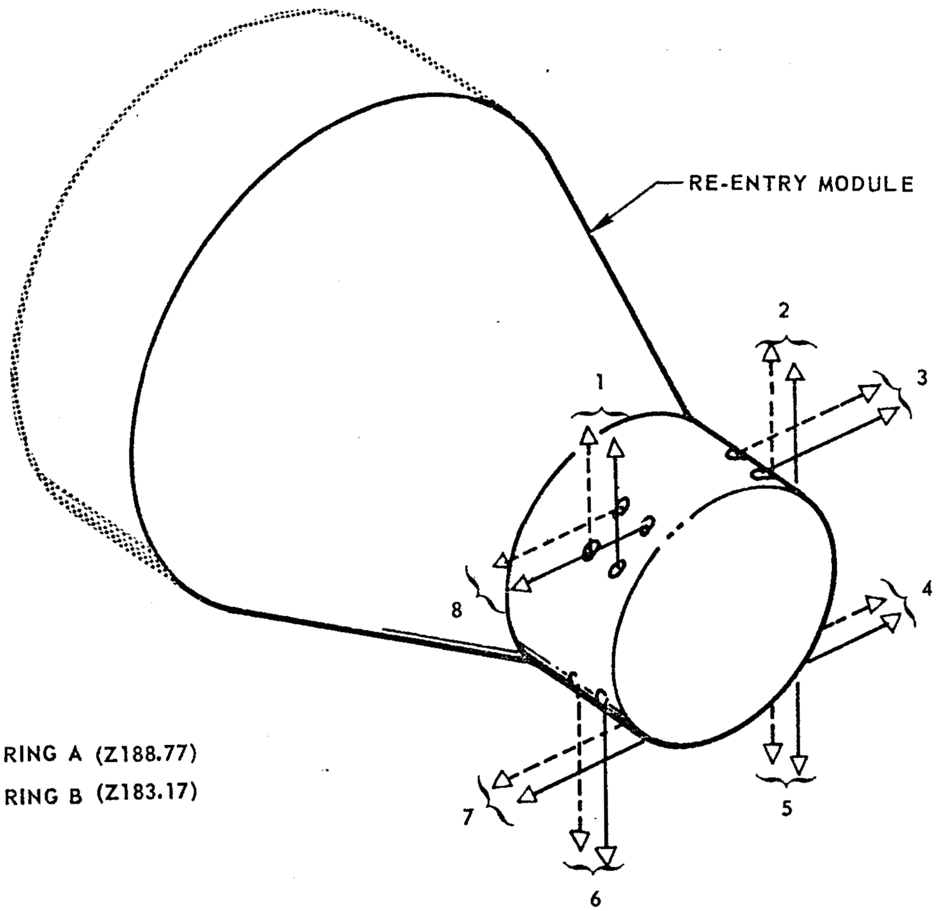
The aft-firing maneuver chambers are used to provide thrust for spacecraft separation from the launch vehicle in normal missions and for high altitude aborts (see Section 3.3 of M.A.C. Report 8611).

Pitch, roll, and yaw torques are obtained by firing pairs of TCA's. Translational acceleration is obtained by firing appropriate TAC's singly or in pairs according to the desired direction of motion. TCA's used for attitude control have a nominal motor axial thrust of 25 pounds, those used for translation aft have a motor axial thrust of 85 pounds, and those used for translation forward, left, right, up, or down have a motor axial thrust of 100 pounds.

3.3 DESCRIPTION AND OPERATION.- The components are arrayed as shown schematically in Figure 2 for the two day mission and Figure 3 for the fourteen day mission and are installed as shown in Figure 4. In general, system operation may be described as follows. Cold gas is stored under pressure

THRUST CHAMBER ASSEMBLY (TCA) ARRANGEMENT

RE-ENTRY CONTROL SYSTEM



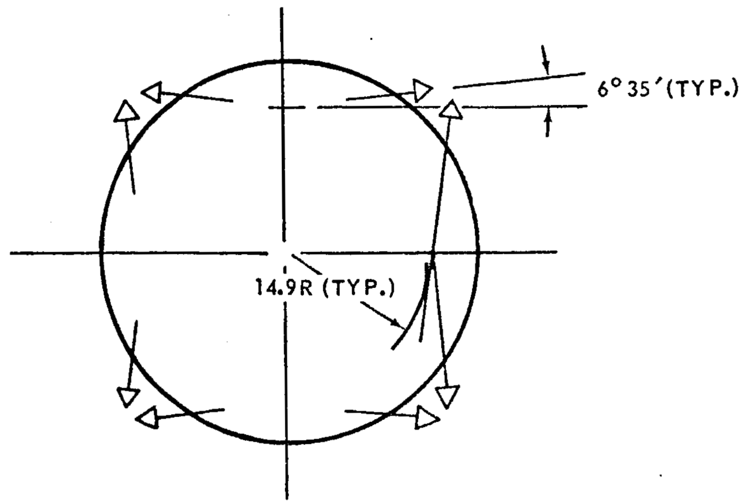
LEGEND:

——— RING A (Z188.77)

– – – – RING B (Z183.17)

16 – 25 LB. THRUST CHAMBERS

FUNCTION	TCA NO.
PITCH UP	5 AND 6
PITCH DOWN	1 AND 2
YAW RIGHT	3 AND 4
YAW LEFT	7 AND 8
ROLL CLOCKWISE	3 AND 7
ROLL COUNTERCLOCKWISE	4 AND 8



NOTES:

1. DIRECTIONS REFERENCED TO ASTRONAUTS' ORIENTATION.
2. ARROWS INDICATE FLOW OF EXHAUST GASES.

Figure 1

CODE

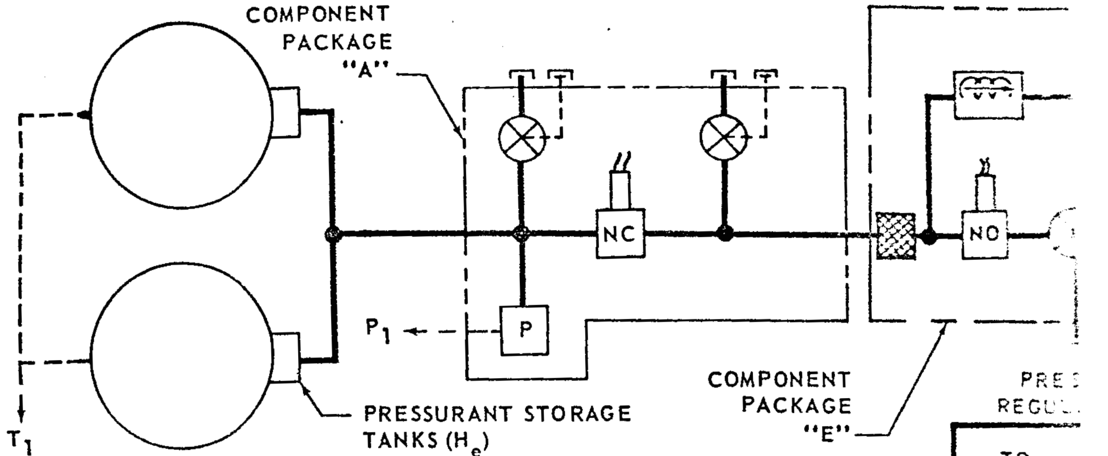
25 LB.

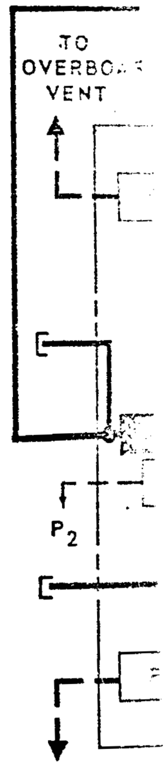
85 LB.

100 LB.

ORBIT ATTITUDE AND MANEUVER SYS
SCHEMATIC– 2 DAY MISSION

PRESSURANT GROUP





LEGEND

TCA	THRUST CHAMBER ASSEMBLY
	CONNECTED
	NOT CONNECTED
T_1, T_2 & T_3	TEMPERATURE (TRANSMITTED TO INSTRUMENT PANEL INDICATOR)
P_1 & P_2	PRESSURE (TRANSMITTED TO INSTRUMENT PANEL INDICATOR)
	MANUAL VALVE
NC	CARTRIDGE-ACTUATED VALVE (NORMALLY CLOSED)
NO	CARTRIDGE-ACTUATED VALVE (NORMALLY OPEN)
P	PRESSURE TRANSDUCER
R	RELIEF VALVE
	SOLENOID VALVE (NORMALLY CLOSED)
	PRESSURE SWITCH
	BURST DIAPHRAGM
	CHECK VALVE
	FILTER
	GROUND TEST CONNECTION
	MOTOR OPERATED VALVE
	FLOW LIMITING ORIFICE
	25 LB. THRUST TCA (YAW, PITCH, & ROLL)
	100 LB. THRUST TCA (TRANSLATE FORWARD)
	PROPELLANT LINE GUILLOTINE
	100 LB. THRUST TCA (TRANSLATE RIGHT, LEFT, UP, OR DOWN)
	85 LB. THRUST TCA (TRANSLATE AFT)

ATTITUDE AND MANEUVER SYSTEM SCHEMATIC- 2 DAY MISSION

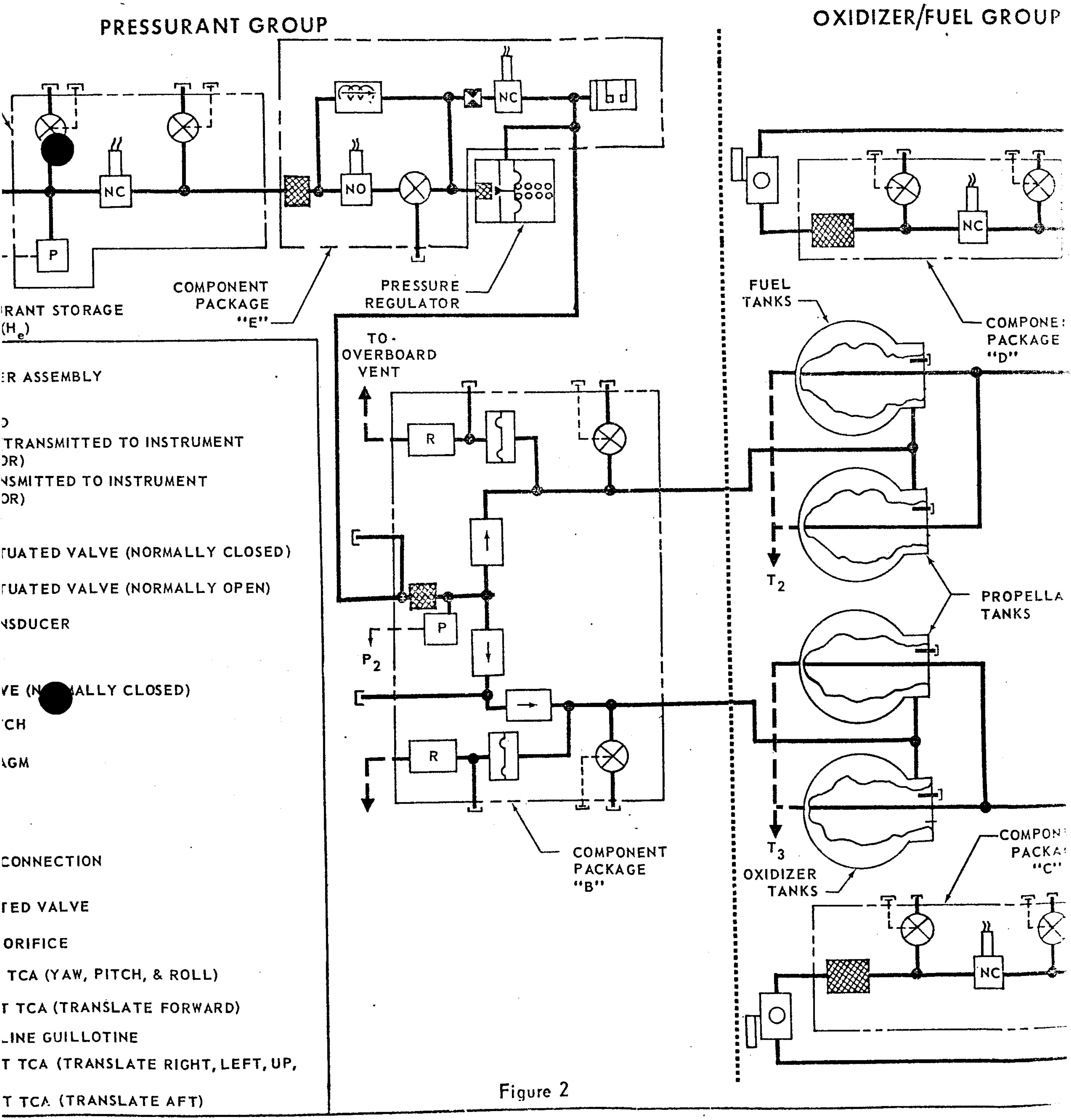
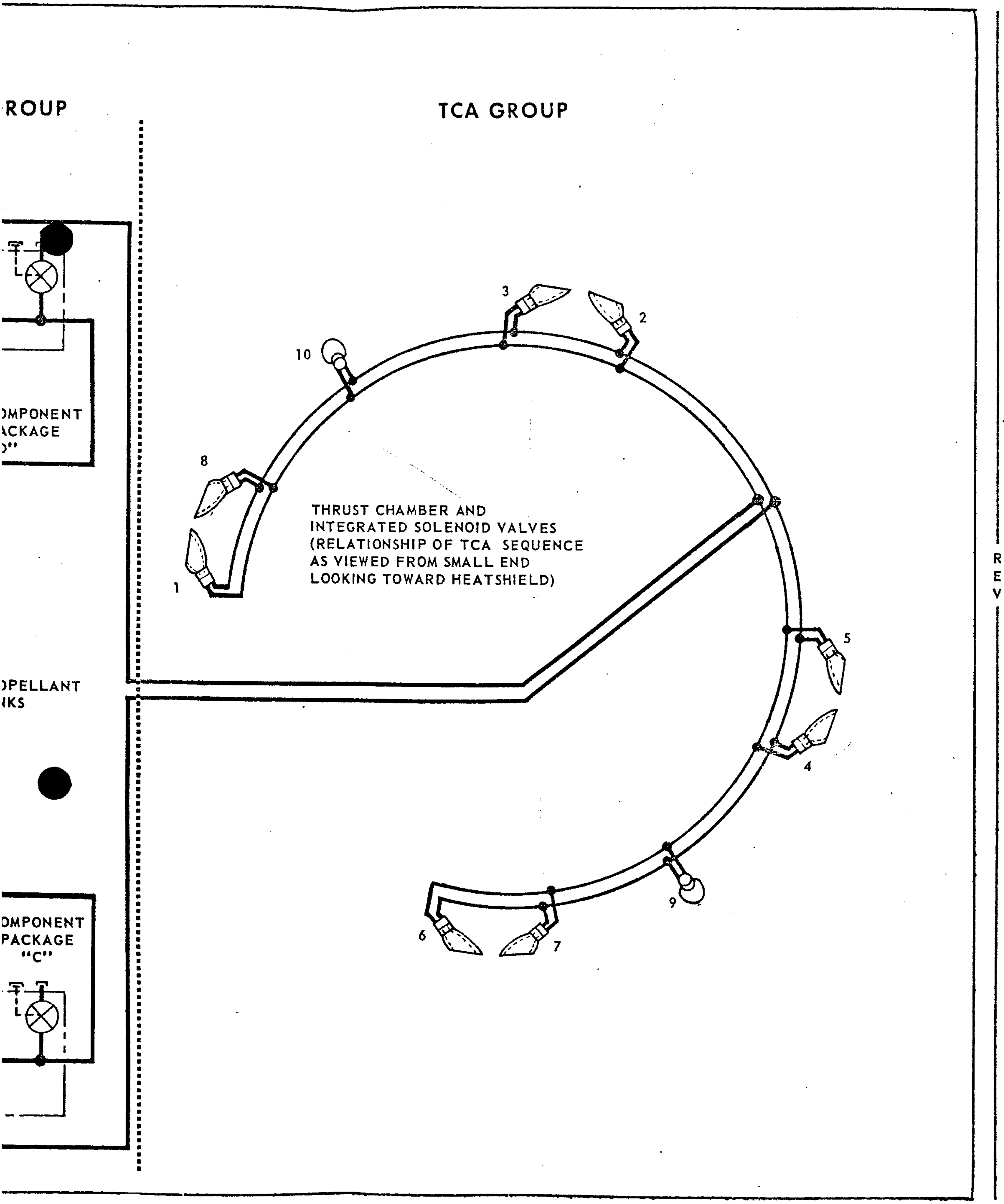


Figure 2



ROUP
TCA GROUP
OMPONENT
ACKAGE
"
3
2
10
8
THRUST CHAMBER AND
INTEGRATED SOLENOID VALVES
(RELATIONSHIP OF TCA SEQUENCE
AS VIEWED FROM SMALL END
LOOKING TOWARD HEATSHIELD)
1
5
OPELLANT
NKS
4
9
6
7
OMPONENT
PACKAGE
"C"
R
E
V

ORBIT ATTITUDE AND MANEUVER SYSTEM SCHEMATIC-14 DAY MISSION

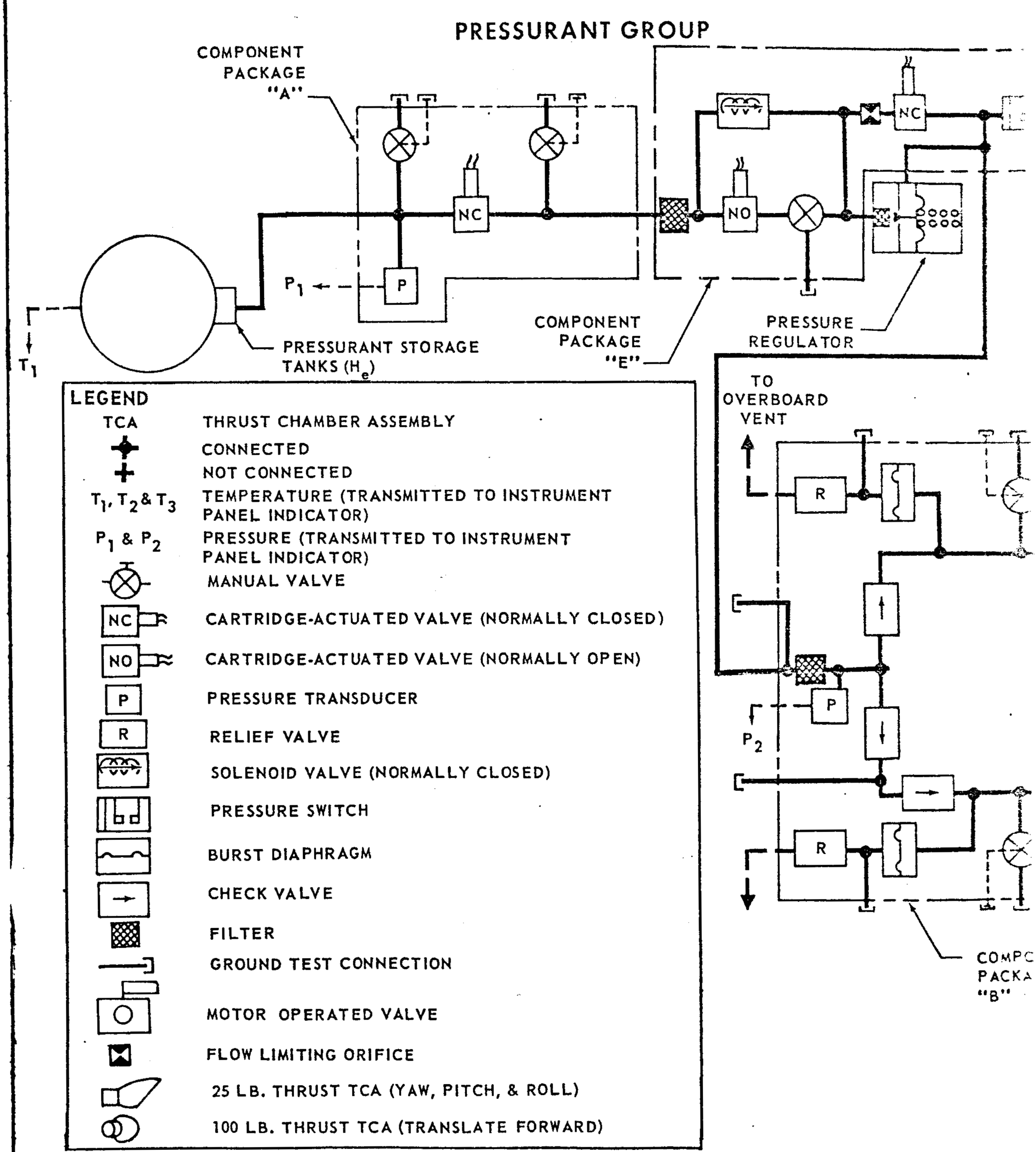


Figure 3

ITUDE AND MANEUVER SYSTEM
HEMATIC-14 DAY MISSION

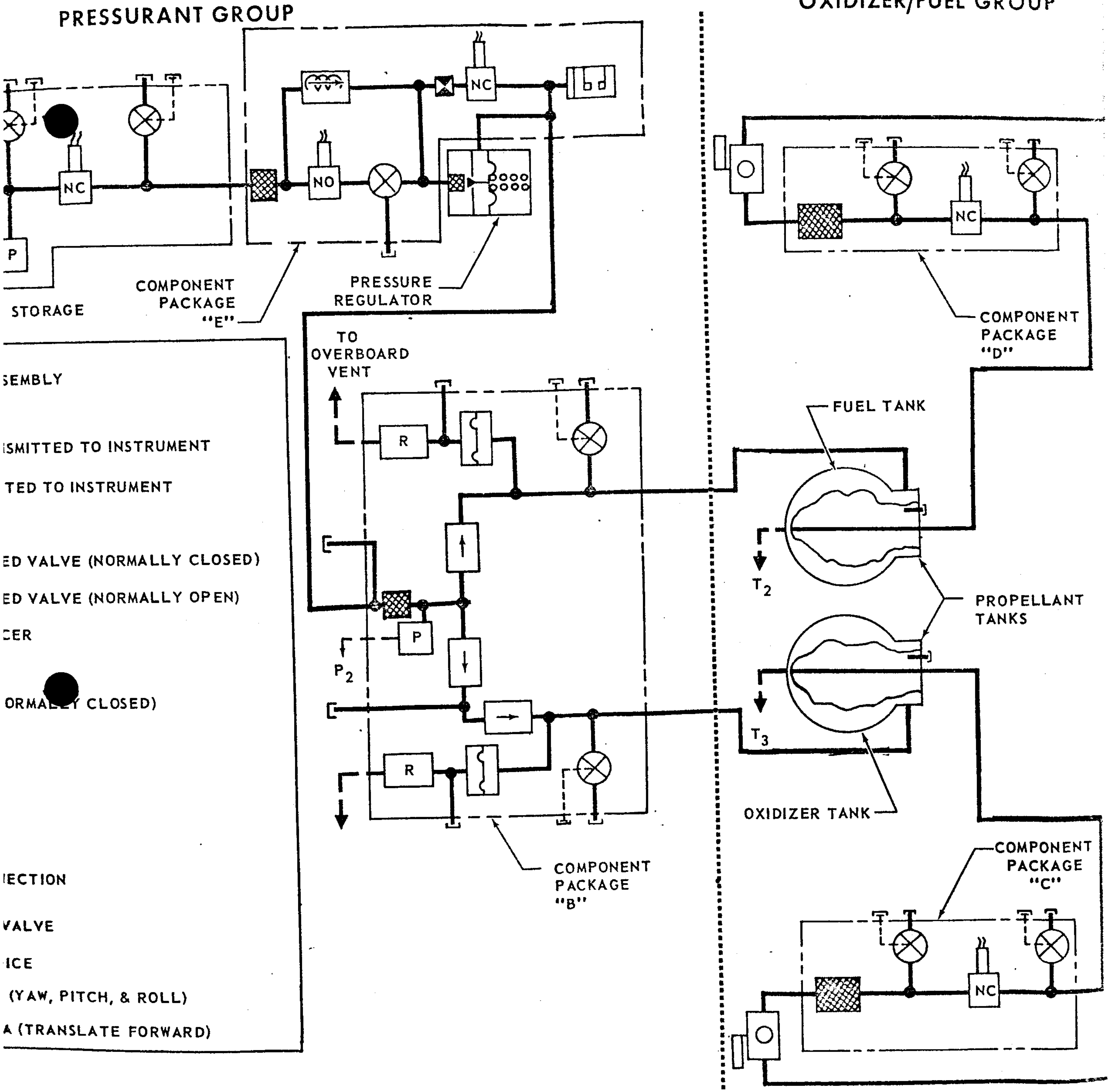
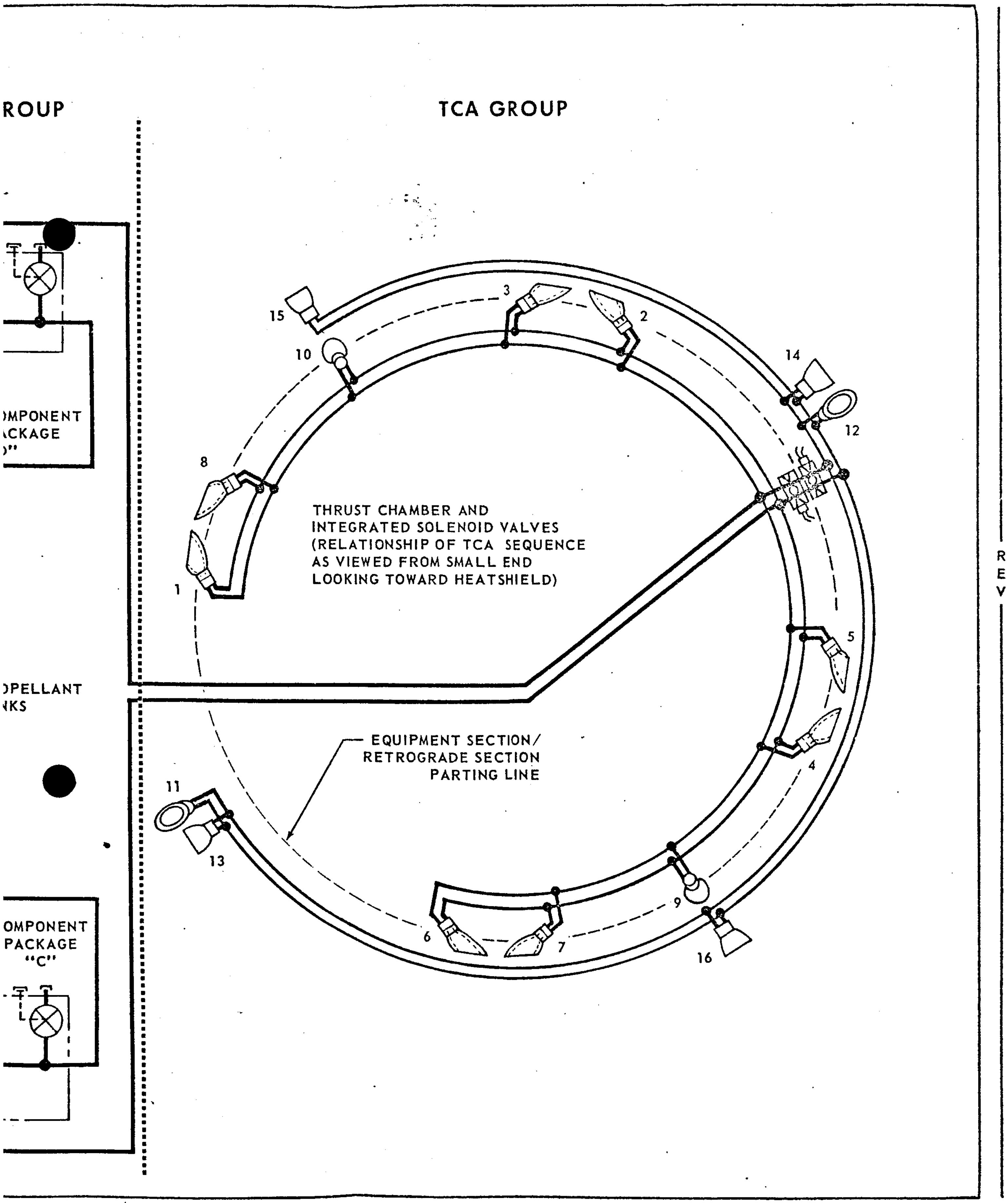


Figure 3



ROUP
TCA GROUP
)MPONENT
\CKAGE
)"
THRUST CHAMBER AND
INTEGRATED SOLENOID VALVES
(RELATIONSHIP OF TCA SEQUENCE
AS VIEWED FROM SMALL END
LOOKING TOWARD HEATSHIELD)
)PELLANT
\KS
EQUIPMENT SECTION/
RETROGRADE SECTION
PARTING LINE
OMPONENT
PACKAGE
"C"
1
2
3
4
5
6
7
8
9
10
11
12
13
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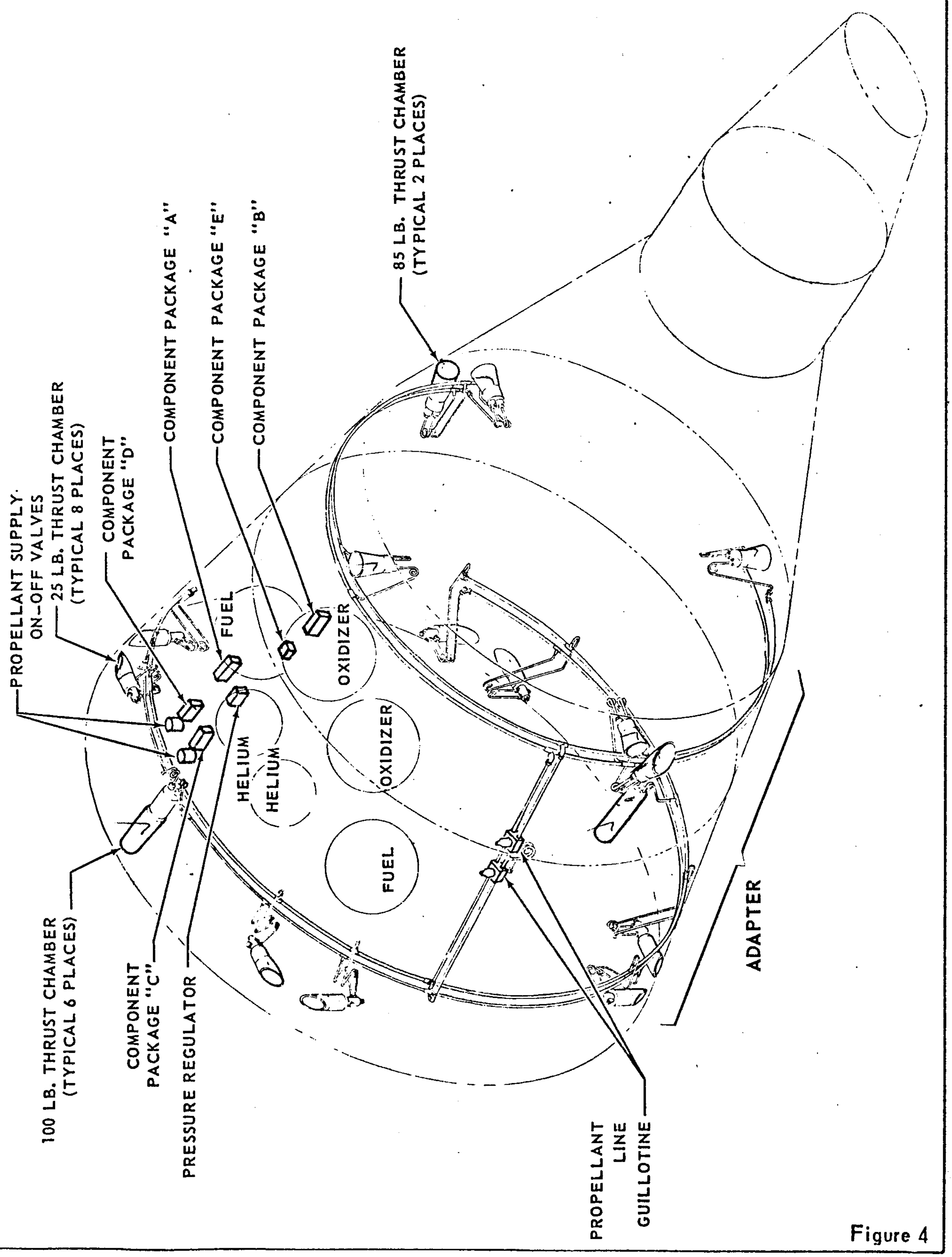
15
16
R
E
V



ORBIT ATTITUDE AND MANEUVER SYSTEM COMPONENT INSTALLATION

Figure 4

NEW

3.3 DESCRIPTION AND OPERATION.- (Continued)

in the pressurant storage tank and held therein by a normally closed cartridge-actuated valve. When the system is to be activated, the cartridge valve is opened and the pressurant flows to the pressure regulation group. The gas pressure is reduced at the regulator to a preset value and this regulated pressure is imposed upon each of the propellant tanks to pressurize the propellants. These tanks are of the flexible collapsing bladder type for positive expulsion of the propellants in the gravity-free environment of space. Simultaneously with the firing of the above mentioned valve, similar valves located downstream from the propellant tanks are opened. The system, with valves open and propellants pressurized, is ready for a firing command. The firing command is received at the thrust chamber propellant valves which open in response, permitting propellant flow to the thrust chamber. The simultaneous introduction of both propellants to the thrust chamber precipitates hypergolic ignition, combustion, and the generation of thrust.

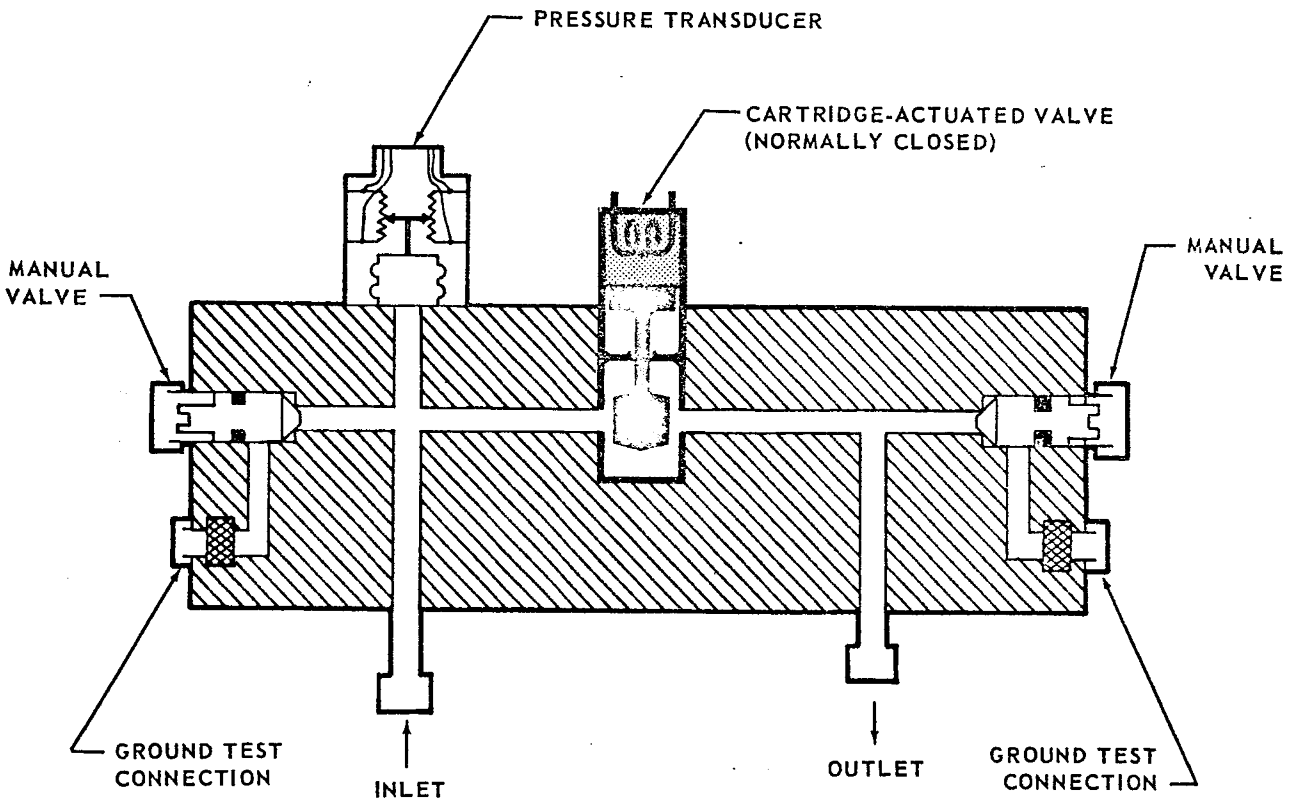
As shown on Figures 2 and 3, part of the OAMS is designed on a modular basis, with the modules consisting of several components conveniently and compactly arranged to reduce weight, eliminate leaks, and facilitate installation, testing and servicing of the system. There are six such modules: component packages "A", "B", "C", "D", and "E", and the TCA's. In addition, there are the pressurant storage tank(s), pressure regulator, propellant tanks, propellant supply on-off valves, and propellant line guillotines.

The components are divided into three main groups: a pressurization group, oxidizer and fuel groups, and TCA group. The pressurization group consists of a pressurant storage tank(s), component packages "A" and "B", and a pressure regulation group (a pressure regulator/component package "E" combination). The oxidizer and fuel groups are similar, consisting of propellant tanks, component packages "C" and "D", and propellant supply on-off valves. Each TCA in the TCA group contains propellant valves, injectors, and thrust chambers. A detailed description of the components comprising these groups is contained in the following paragraphs.

The pressurant storage tank is an all-welded, spherical tank. Helium gas is stored in the tank at a nominal storage pressure of 3000 psig. Either one or two tanks are provided depending on the mission to be performed. When two tanks are used, they are identical in size. Each tank is 15.20 inches in outside diameter and has an internal volume of 1696.0 cubic inches.

Component package "A", Figure 5, consists of a pressure transducer, a normally closed cartridge-actuated valve, and two manual valves. The pressure transducer is used to monitor the pressure of the stored high pressure gas. The cartridge valve is used to isolate the pressurant from the remainder of the system prior to system activation. The manual valve upstream of the cartridge valve is used for filling, draining, and purging of the pressurant while the manual valve downstream from the cartridge valve is used during ground checkout of the pressure regulation group.

COMPONENT PACKAGE "A" SCHEMATIC



N
E
W

Figure 5

3.3 DESCRIPTION AND OPERATION.- (Continued)

The pressure regulation group is shown schematically in Figure 6. The regulator, Figure 7, provides the primary mode of pressure regulation of the pressurant gas, the nominal pressure setting for regulation being 280 psig. It is of the single-stage, conventional mechanical-pneumatic type. A 2-micron inlet filter is used to reduce the contaminants in the gas to an acceptable level, thereby increasing the reliability of the regulator.

Component package "E", Figure 8, provides the secondary mode of pressure regulation of the pressurant gas. It consists of a normally open cartridge-actuated valve, a normally closed solenoid by-pass valve, a normally closed cartridge-actuated valve, a pressure switch, and a manual valve. In the normal mode of operation gas flows through the normally open cartridge valve and the regulator. In the event of failure of the regulator, such that the output pressure rises towards a level which would cause the system overpressure relief components to function, the pressure switch intervenes and causes the normally open cartridge valve upstream of the regulator to be closed. Pressure then may be controlled by the crew's manual switch, with control information obtained from the pressure transducer in component package "B" and an instrument panel indicator. Thus, additional pressure increase is prevented and a manual electro-mechanical mode of regulation is initiated. In this mode the opened valve permits gas flow and rise of pressure. This cycle is repeated manually as required to maintain system pressure for the propellant at a satisfactory level. If sufficient pressurant flow cannot be achieved through the failed regulator, a by-pass line may be opened by actuating a switch which opens the normally closed cartridge valve. Provision is made in the circuitry to insure that both cartridge valves are fired if the by-pass is opened. This prevents inadvertent by-pass of both the regulator and the solenoid valve. Fuses are provided in the cartridge valve circuits to prevent excessive electrical power drain in the event that a cartridge bridge wire element should fire to give a short circuit. The manual valve and the solenoid valve are provided for ground checkout of the components. NEW

Component package "B", Figure 9, consists of a pressure transducer, relief valves, burst diaphragms, check valves, manual valves, and ground test connections. The pressure transducer is used to monitor the regulated gas pressure. The burst diaphragms and pressure relief vent valves provide over-pressure protection in the event of failure of the pressure regulation group or excessive temperature cycling. The burst diaphragms are used to provide assured zero leakage (until activated) pressure relief devices. If this were the sole protective element, a single actuation would result in venting of the total supply of pressure. However, the addition of the pressure relief valves avoids this and restricts the venting to that required to correct conditions of a transient type and keep the system pressure at a safe level (i.e., if the regulation failure is momentary in nature, the relief valves reseat and permit normal system operation thereafter). Such a situation can occur in the event of an abnormal thermal cycle coupled with a low rate of propellant consumption. REV

ORBIT ATTITUDE AND MANEUVER SYSTEM

PRESSURE REGULATION GROUP

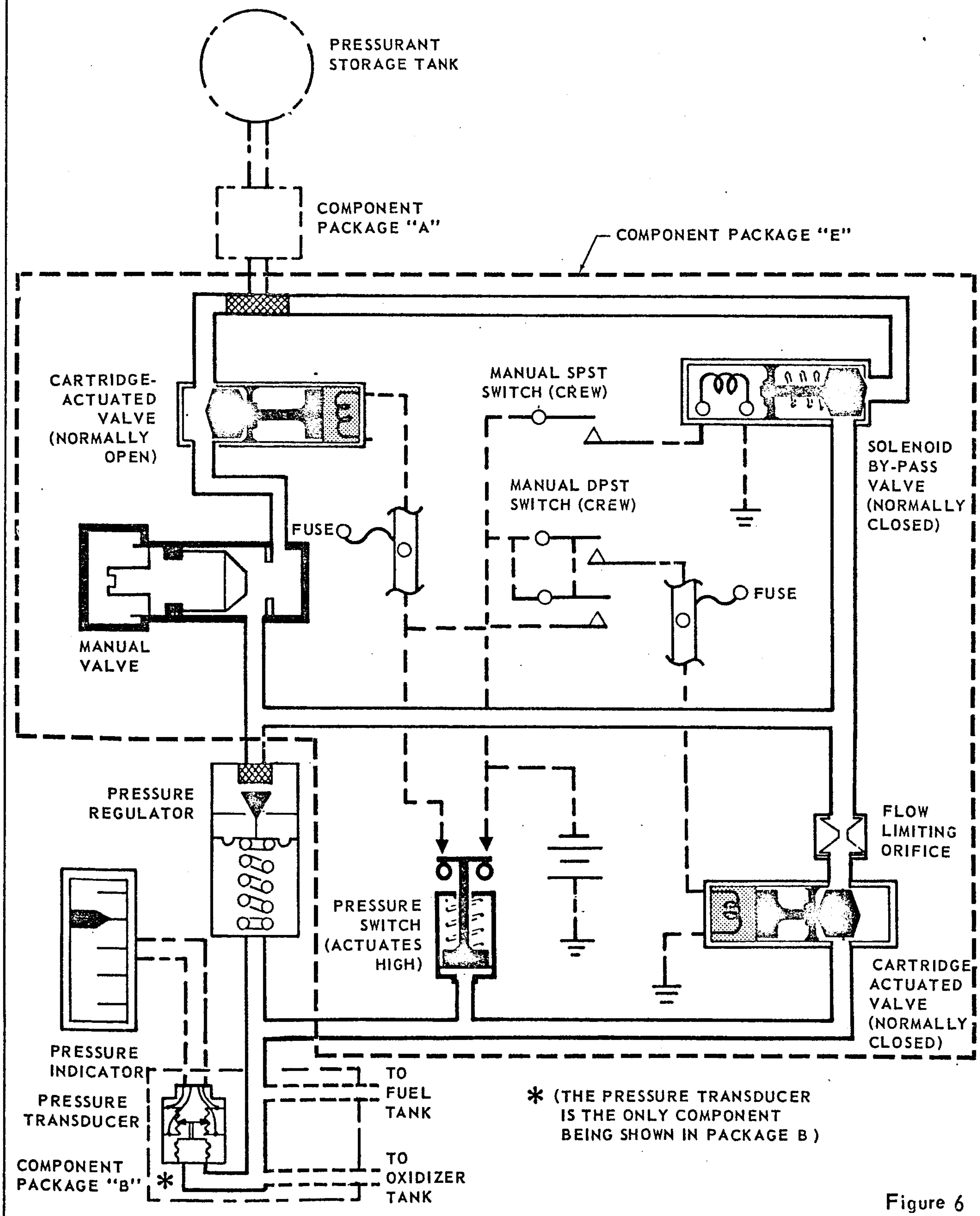


Figure 6

PRESSURE REGULATOR

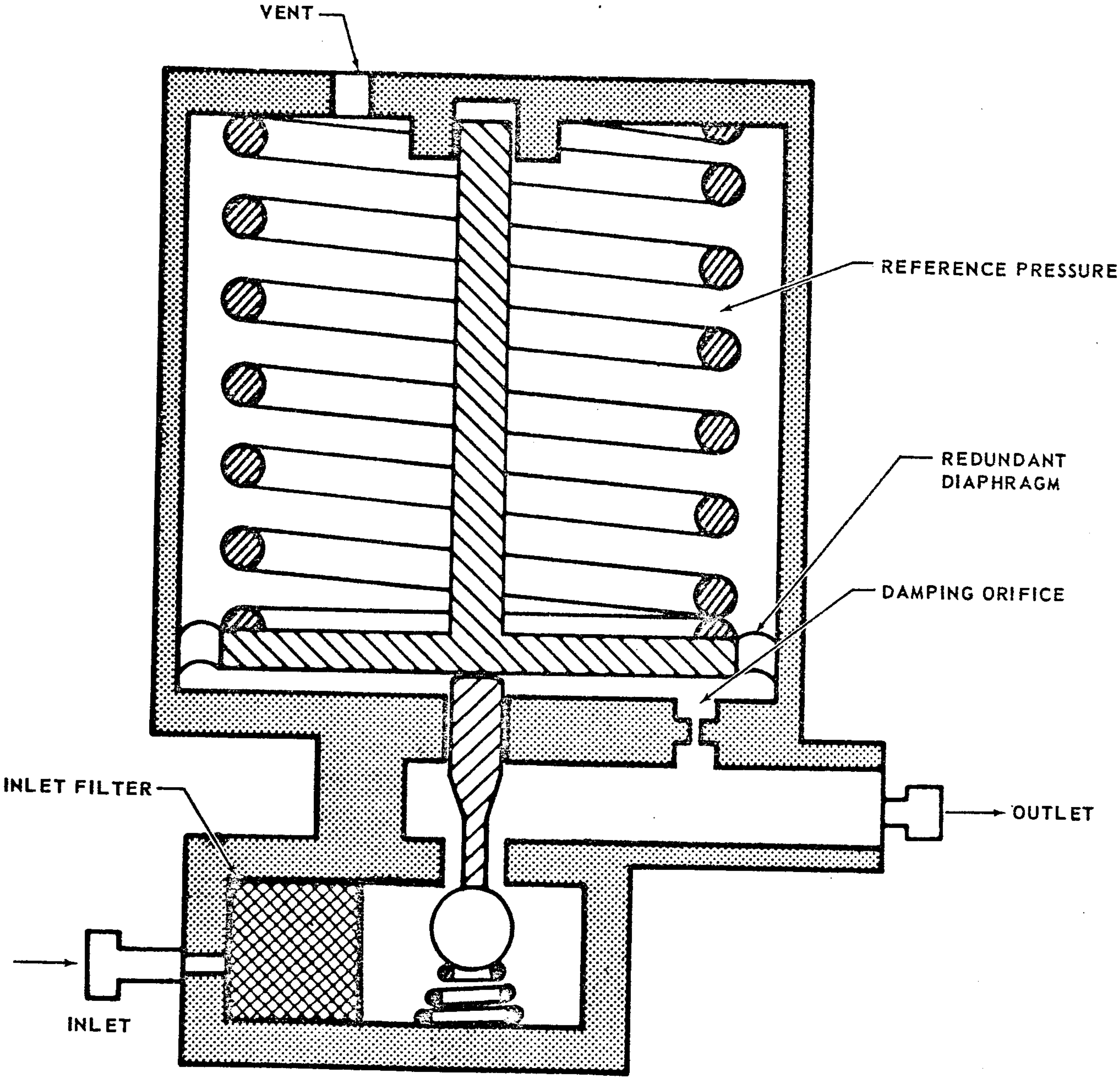


Figure 7

NEW

COMPONENT PACKAGE "E" SCHEMATIC

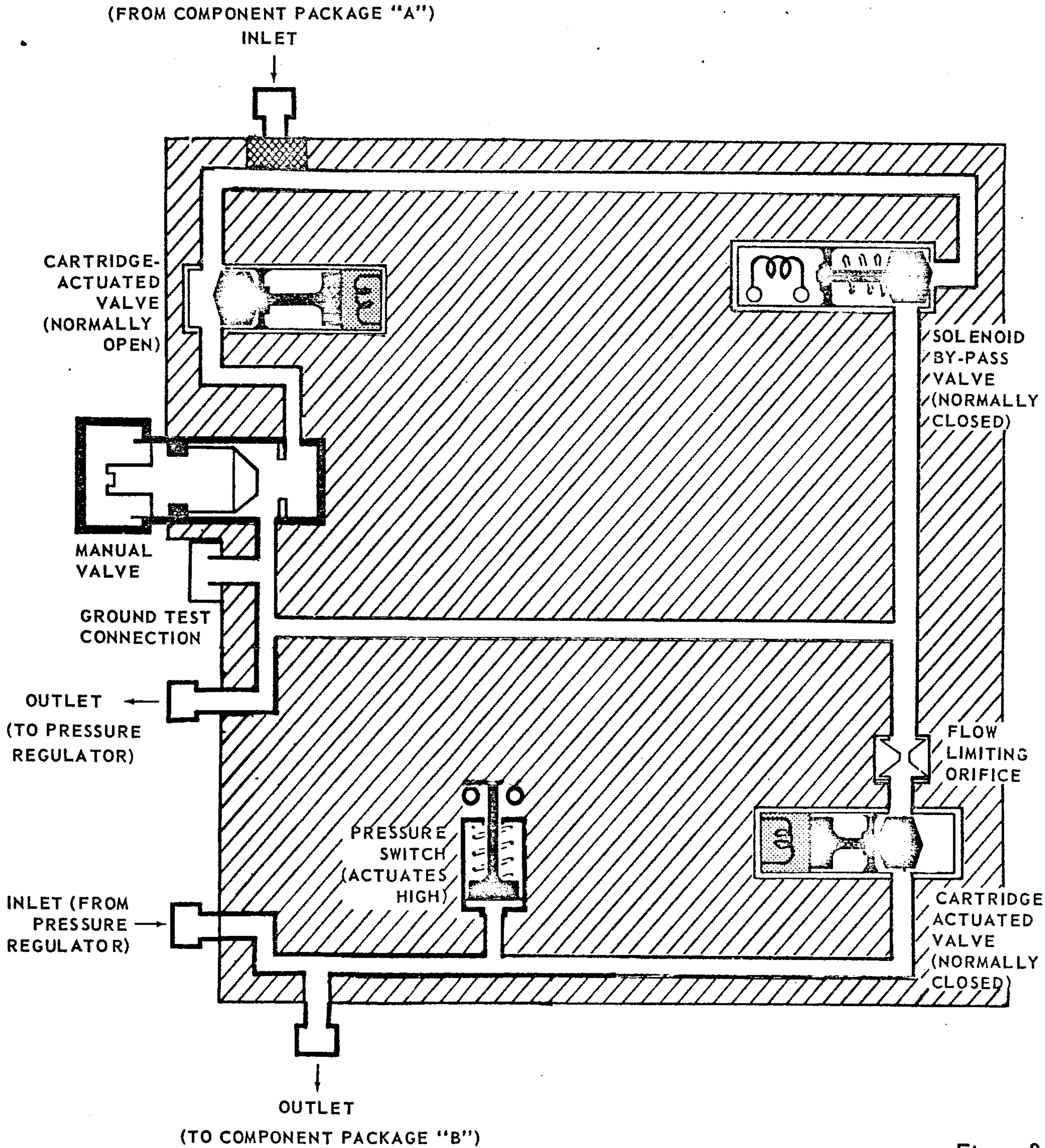


Figure 8

NEW

COMPONENT PACKAGE "B" SCHEMATIC

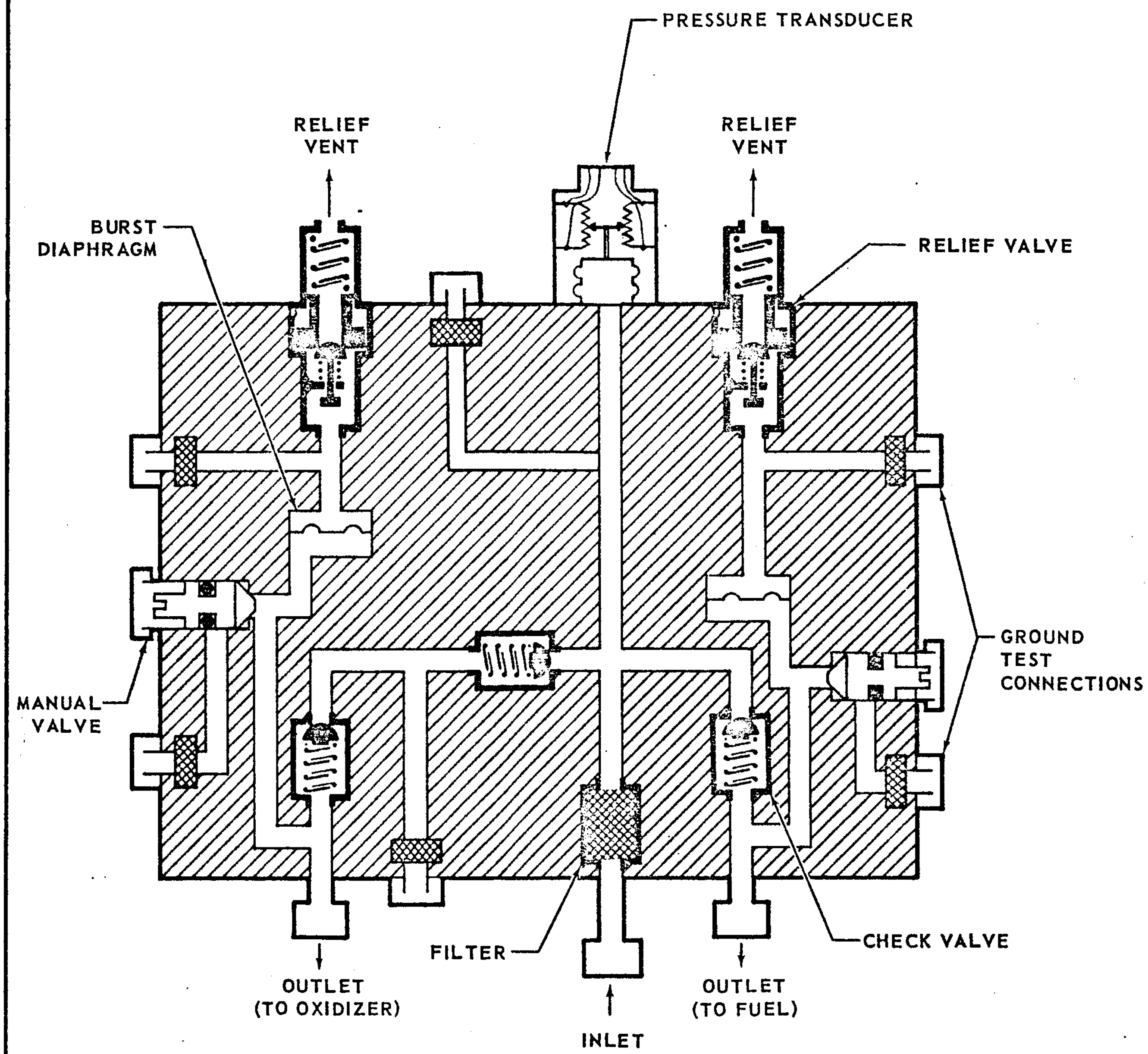


Figure 9

NEW

3.3 DESCRIPTION AND OPERATION.- (Continued)

A check valve is provided upstream of the fuel propellant tank to prevent backflow of fuel into the gas system, should the expulsion bladder fail. Check valves are provided upstream of the oxidizer propellant tank to prevent backflow of oxidizer vapor into the gas system. Two are used for double protection against oxidizer vapor which will permeate the teflon expulsion bladder. The ground test connections are used for component checkout and the manual valves are used for ground checkout and servicing.

The propellant tanks are spherical. They are of the positive expulsion type, with expulsion bladders which are compatible with the propellants to be contained. The bladders in the fuel and oxidizer tanks are made of teflon and can require replacement as they have a limited expulsion or collapsing cycle service life (not time limited). A flow path is provided through the propellant portion of the tanks for bleeding, purging, and drying. This port is designed such that each flow path to the atmosphere is sealed twice to increase the reliability of the tanks. The oxidizer tank is 22.00 inches in outside diameter and the fuel tank is 20.13 inches in outside diameter. The fluid volume capacity is 5355.0 cubic inches for the oxidizer tank and 4130.0 cubic inches for the fuel tank. The charged fluid volume capacity at 160°F for the design propellant weight is 5100.0 cubic inches for the oxidizer tank and 3900.0 cubic inches for the fuel tank.

NEW

Component packages "C" and "D", Figure 10, contain essentially the same components: A normally closed cartridge-actuated valve, two manual valves, and a filter. The cartridge valves are used to isolate the propellants from the remainder of the system prior to system activation. The manual valves upstream of the cartridge valves are used for filling, draining, and purging of the propellants while the manual valves downstream from the cartridge valves are used for ground checkout of downstream component function. The filters are used to reduce the particle contamination of the propellants to a level acceptable to the TCA's.

Downstream from component packages "C" and "D" are the propellant supply on-off valves. These motor operated valves are inactive during normal system operation. Only in case of failure (open) of a TCA propellant valve (or valves) or other serious leak downstream would these valves be closed to reduce propellant loss. They would then be opened only to allow firing of the TCA's for attitude changes and maneuvers and reclosed until thrust is again required.

All TCA's are installed submerged beneath the spacecraft moldline. Each one consists of two thrust chamber propellant valves, two calibration orifices, a fuel and oxidizer injection system, a combustion chamber, and an expansion nozzle. A typical 25 pound TCA is shown in Figure 11. The propellant valves are quick acting, normally closed solenoid valves which open upon application of an appropriate electrical signal to permit flow of oxidizer or fuel to

COMPONENT PACKAGES "C" AND "D" SCHEMATIC

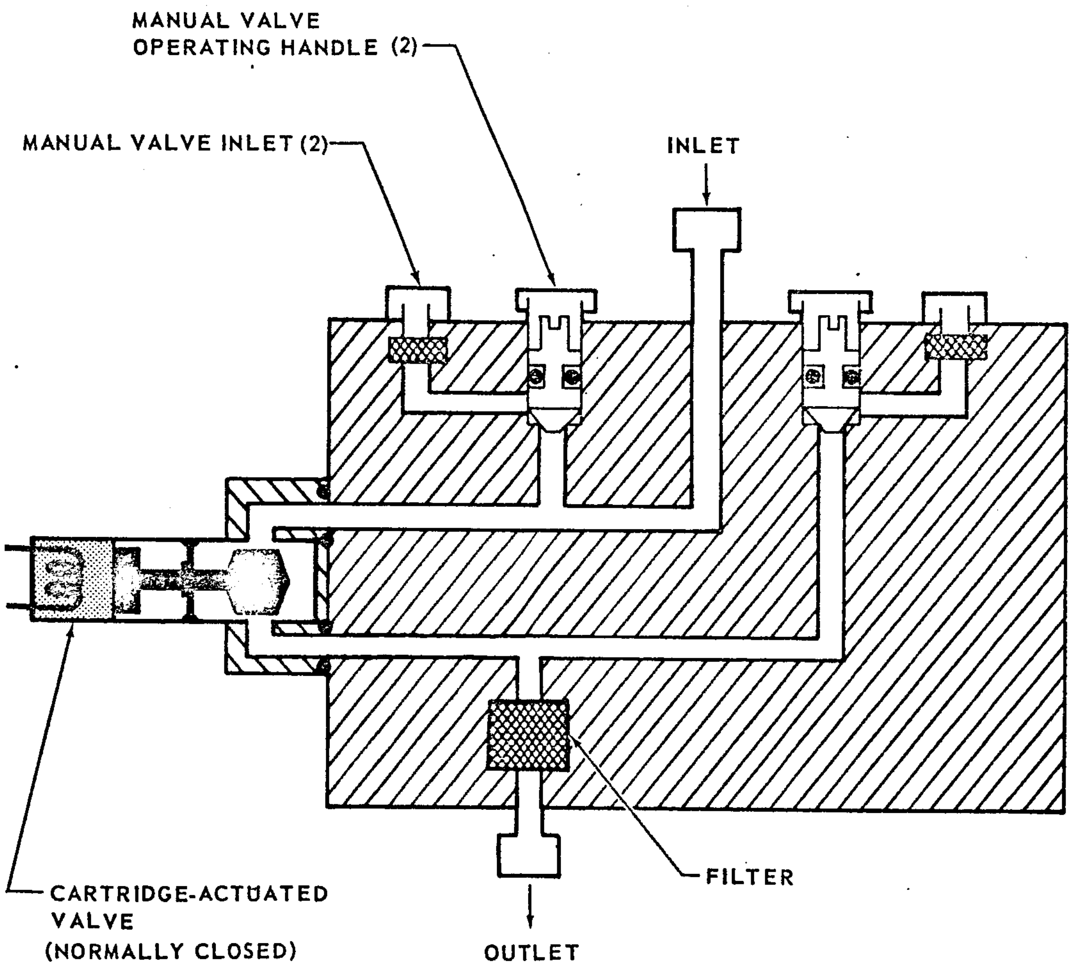
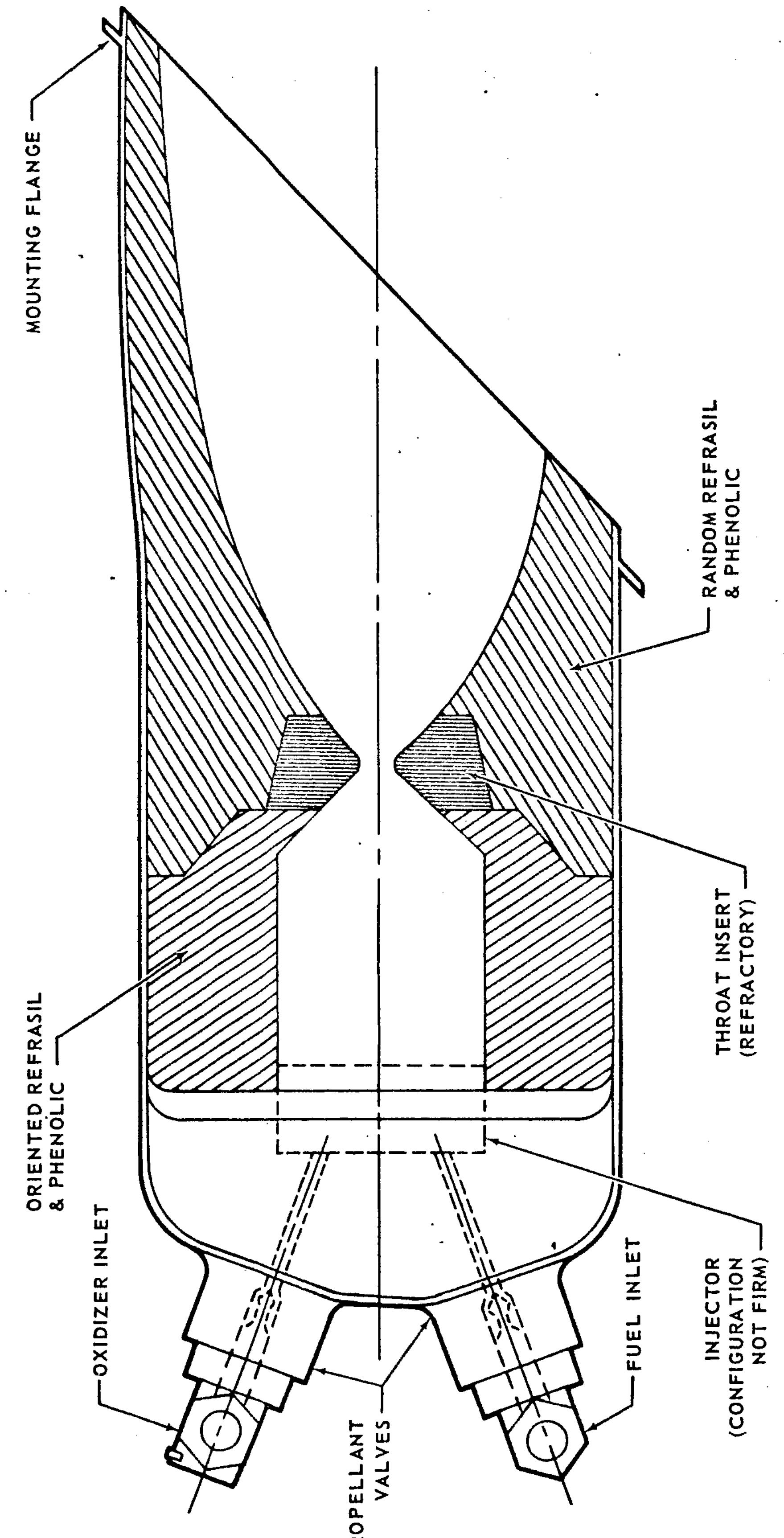


Figure 10

NEW

TYPICAL THRUST CHAMBER (25 LB. OAMS)

CONSTRUCTION OF "CRES".
UNLESS OTHERWISE NOTED



NOTE:
VALVE SECTION ROTATED 90° WITH RESPECT
TO CHAMBER FOR CLARITY.

Figure 11

3.3 DESCRIPTION AND OPERATION.- (Continued)

the injector to which they are fitted. The injector utilizes precise jets which impinge the fuel and oxidizer on one another for controlled mixing and good combustion efficiency. The calibration orifices are trim devices used in conjunction with the propellant valves and the injectors to adjust the flows to the design flow levels. The trim orifices are adjusted and fixed during TCA acceptance testing. The combustion chamber is the enclosed area between the injector face and the throat of the nozzle. The expansion nozzle is bell-shaped and contoured to terminate flush with the moldline of the spacecraft. The combustion chamber and the nozzles are lined with ablation material and insulation to control external wall temperature. Seals are provided between the nozzle and the spacecraft skin to prevent the backflow of exhaust gas into the spacecraft. A protective cover or plug is provided to protect the thrust chamber from entry of foreign matter when the TCA is not in use. The cover or plug is manually removed prior to launch and/or jettisoned in flight by the first start. NEW

For the two day configuration a portion of the OAMS (six TCA's) is located in the adapter retrograde section while the remainder is located in the adapter equipment section. Because these sections are jettisoned in two stages prior to re-entry (the equipment section approximately thirty seconds prior to actual retrograde firing and the retrograde section approximately sixty seconds later), guillotines are provided to sever the fuel and oxidizer lines to permit separation of the portion of the OAMS located in the equipment section from the six TCA's in the retrograde section. The guillotines, Figure 12, are cartridge-actuated devices which cut and seal positively the fuel and oxidizer tubing leading to the TCA's in the retrograde equipment section. Redundant guillotines are utilized to assure separation. When the fourteen day arrangement is used, the total OAMS system is jettisoned prior to retrograde since it is entirely located in the adapter equipment section. REV

PROPELLANT LINE GUILLOTINE

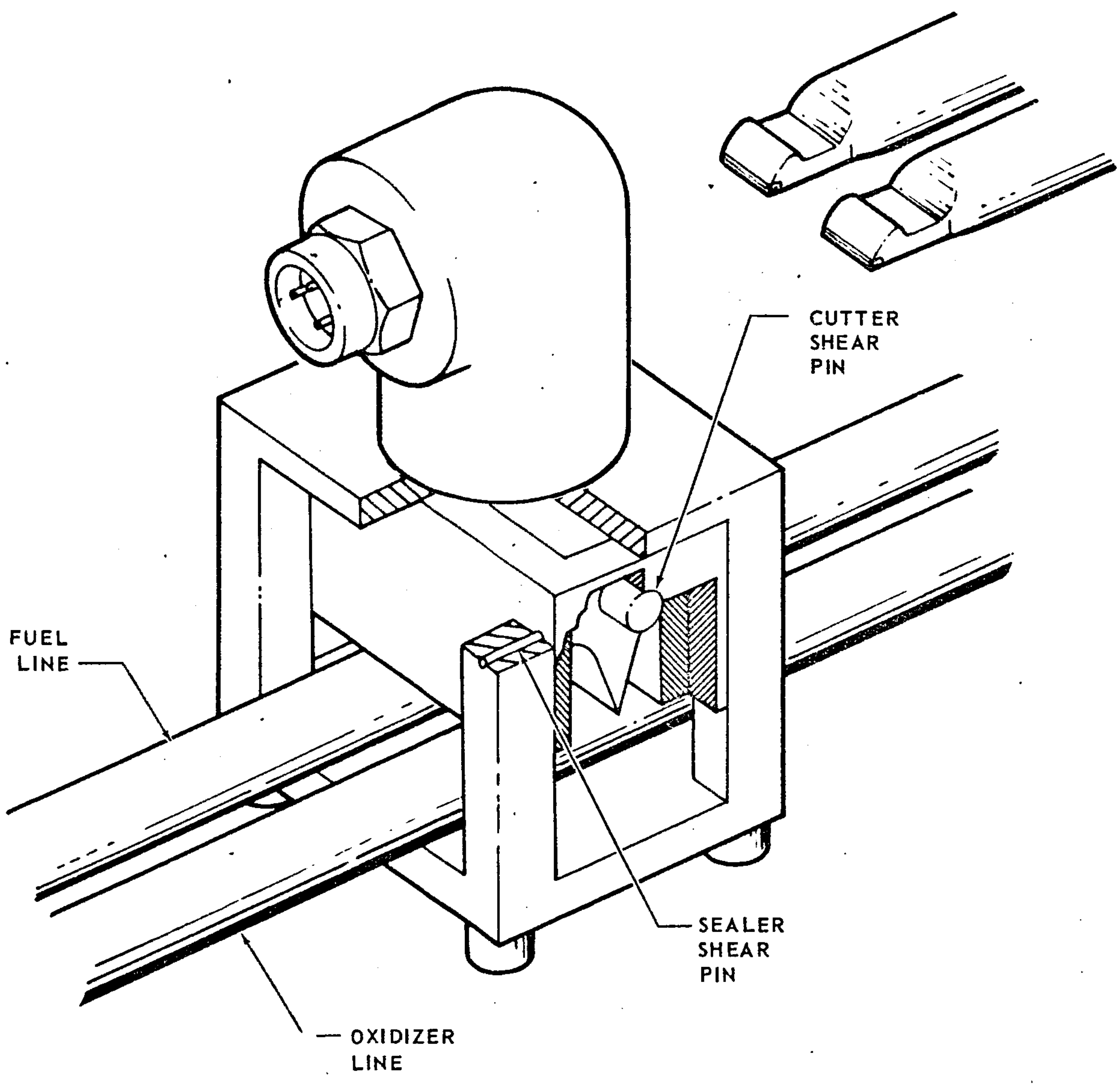


Figure 12

N
E
W

3.3 DESCRIPTION AND OPERATION.- (Continued)

A temperature and pressure indicator and a manual switching device, Figure 13, are located on the crew's instrument panel to provide individual readouts of specific temperatures and pressures sensed at various locations in the OAMS. These readouts are manually selected by means of the switching device and are displayed on the indicator. The temperature and pressure of the stored high pressure gas and the regulated gas can be used to:

A. Provide an indication of the pressurization capability available for the remainder of the mission.

B. Evaluate regulator operation.

C. Provide a secondary means of determining propellant quantity in the tanks.

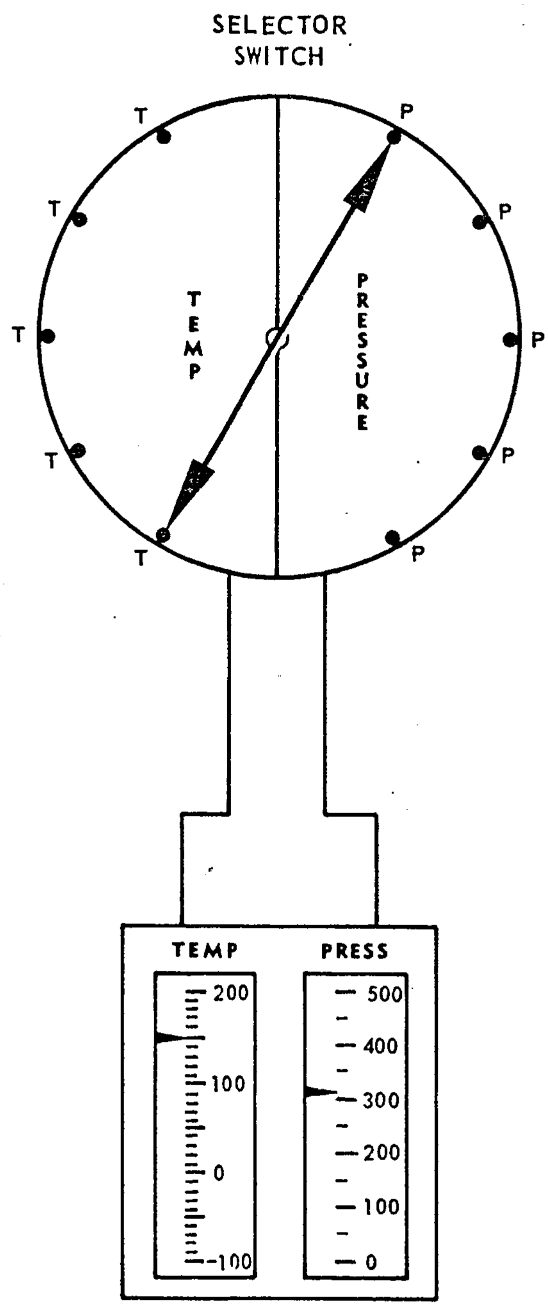
REV

The pressure side of the indicator is scaled to read from 0 to 500 psig. This is compatible with the expected pressure reading to be obtained from the regulated pressure. However, it must be mentally multiplied by 10 for the pressure reading of the stored gas. The temperature side of the indicator is scaled to read from -100 to +200°F and is compatible with the expected temperature reading to be obtained from the stored gas and the regulated gas.

A propellant quantity guaging system is provided to indicate the amount of oxidizer and fuel remaining in the OAMS propellant tanks. Individual readouts of the oxidizer and fuel are displayed on the crew's instrument panel as shown in Figure 14.

NEW

PROPELLANT TEMPERATURE AND PRESSURE INDICATOR AND SELECTOR SWITCH

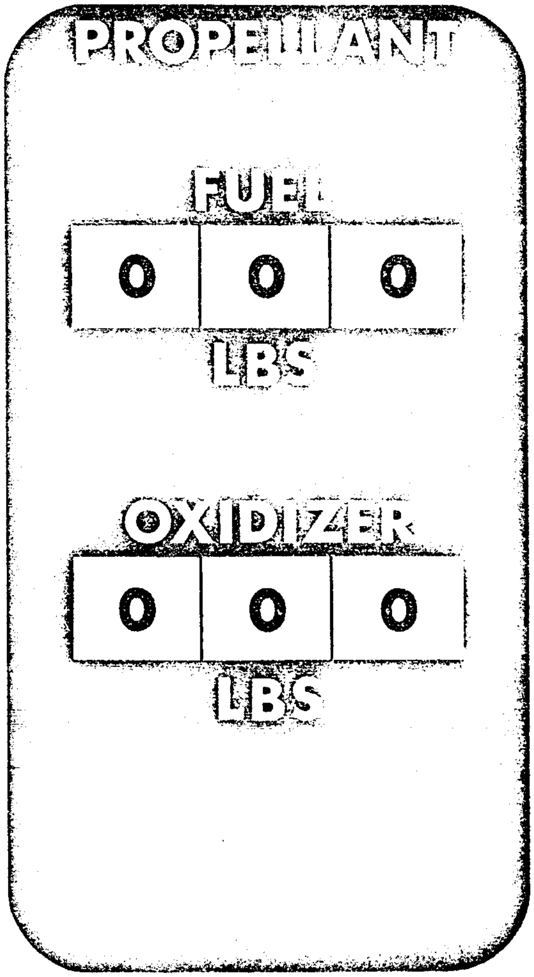


TEMPERATURE AND PRESSURE
INDICATOR

Figure 13

NEW

PROPELLANT DISPLAY



NEW

Figure 14

3.4 DESIGN CRITERIA.- A propulsion system, capable of performing the OAMS mission, was evolved from the design criteria listed below:

....Storable propellants having an advanced development background.

....Pure couples for roll control.

....A nozzle expansion ratio optimized for minimum over-all system weight.

....Pressurant storage pressure optimized for minimum over-all system weight.

....Helium used for pressurant for minimum over-all system weight.

....Compatible materials (and no dissimilar metals) for all component parts except the static seals in the high pressure manual valves and various non-exposed parts. In addition, no plating or surface treatment is allowed to make any surface compatible.

....Corrosion resistant steel lines, fittings and components, and titanium tanks and bottles.

NEW

....A butyl rubber bladder for the fuel tanks.

....A teflon bladder for the oxidizer tanks.

....Packaging of several components to reduce weight, eliminate leaks, save space, and facilitate installation, servicing and testing.

....Components interchangeable between the OAMS and the Re-entry Control System to reduce development and cost and increase reliability information; i.e., the pressure regulator and component packages "A" and "B".

....A regulator back-up to provide protection for any mode of primary regulator failure.

....Motor-operated propellant shutoff valves to conserve propellant in the event of a downstream leak.

....A system tailored to M.A.C./Rocketdyne philosophy for servicing and checkout. However, adequate connections and test points are incorporated so that any other selected procedure is not excluded. Design of the system such that functional checks of all components can be made using gas, substitute test fluids, or propellants, with by-passes for component packages "A", "C" and "D".

3.4 DESIGN CRITERIA.- (Continued)

....A diaphragm-relief valve series arrangement to provide assured zero leakage prior to activation of the pressure relief operation and then the limiting of the pressure venting to that required to protect the system.

....All dash-numbered parts and packages installed with threaded fittings.

....No external leak paths through dynamic seals.

....Double and triple seal manual valves for service connections instead of the use of disconnects.

....Cartridge valve seals placed on the pressurant and the propellant tanks for reliable actuation, with a positive solid metal seal.

....Replaceable cartridge-actuated valves in component packages "C" and "D" so that the component does not have to be removed from the system to replace a fired unit.

....Main filters located downstream from the cartridge valves and the ground test connections for protection of downstream components. NEW

....Supplemental filters provided at each solenoid valve, at each fill point, and in each cartridge valve for additional protection.

....Non-replaceable filters for reduced weight and to prevent leakage.

....Check valves to provide protection against accidental propellant mixing in the regulated gas elements.

....Purge connections on the propellant tanks for servicing.

....Multi-expulsion bladders to allow several expulsions for system checkout.

....Individual, non-redundant in-line solenoid valves for TCA propellant valves to take advantage of accumulated development experience.

3.4 DESIGN CRITERIA.- (Continued)

....Identical valves and injectors for all 85 and 100 pound TCA's.

....Identical envelopes for the 100 pound lateral and aft firing TCA's.

....Identical valves and injectors for all 25 pound TCA's in the OAMS and the Re-Entry Control System. Also, all OAMS thrust chambers are identical. NEW

no

....The duty life of the TCA's to include contingencies for all predicted uses.

3.5 DESIGN REQUIREMENTS

3.5.1 INPUTS AND FLUIDS

A. Pressurant.- The cold gas pressurant is helium, Federal Stock No. 6830-283-9842.

B. Propellants.- The bipropellant is:

Oxidizer - Nitrogen tetroxide (N_2O_4) conforming to Specification MIL-P-26539A.

Fuel - MMH - Monomethyl hydrazine ($N_2H_3CH_3$) conforming to Specification MIL-P-27403.

C. Electrical Inputs.- Electrical power for components other than instruments is taken from the common control bus at 22.0 to 30.0 volts D.C. Instrument power is taken from a regulated source at 5.0 volts D.C. ± 0.5%.

3.5.2 PERFORMANCE.- The OAMS exhibits the following vacuum performance characteristics:

A. System Performance	Attitude Control TCA's	Maneuver TCA's
Design thrust level per TCA	25 lbs.	100 lbs. *
Minimum steady state specific impulse	300 $\frac{\text{lb.-sec.}}{\text{lb.}}$	300 $\frac{\text{lb.-sec.}}{\text{lb.}}$
Minimum impulse bit required	.25 lb.-sec.	25 lb.-sec.
Minimum specific impulse for minimum impulse bit	260 $\frac{\text{lb.-sec.}}{\text{lb.}}$	300 $\frac{\text{lb.-sec.}}{\text{lb.}}$
Pulse frequency range	0-6 $\frac{\text{pulses}}{\text{sec.}}$	0-2 $\frac{\text{pulses}}{\text{sec.}}$
Pulse width range	Minimum impulse bit width to continuous	.25 sec. to continuous
Maximum TCA response time - time from application of electrical signal to 90% of maximum chamber pressure	25 milliseconds	50 milliseconds
Maximum TCA shutdown time-time from removal of electrical signal to 2% of maximum chamber pressure	7 milliseconds	50 milliseconds

REV

* The TCA's used for translation aft are derated to 85 lbs. thrust.

3.5.2 PERFORMANCE.- (Continued)

B. Other System Parameters	Attitude Control TCA's	Maneuver TCA's
Flow rate - at mixture ratio (O/F) of 2.0		
Oxidizer	.0555 lbs/sec.	.222 lbs/sec.
Fuel	.0278 lbs/sec.	.111 lbs/sec.
Mixture ratio - ratio of pounds of oxidizer to pounds of fuel injected into each TCA		2.0 ± 1%
Regulated pressure		280 psig
TCA chamber pressure		150 psia
Burst diaphragm rupture pressure range		420-500 psig
Relief valve operating pressure range		380-430 psig

REV

3.5.3 WEIGHTS.- Target weights for the Orbit Attitude and Maneuver System are as follows at 15°F:

		Mission 2 Day		Mission 14 Day
A. System Dry Weight		303.3 lbs.		181.0 lbs.
Components	(204.0)		(100.2)	
Lines	(16.6)		(13.4)	
Structure and Electrical	(82.7)		(67.4)	
B. Propellant Weight (Loaded)		724.0		241.0
C. Propellant Weight (Usable)		692.0		226.0
D. Propellant Weight (Trapped & Residual)		32.0		15.0
E. Pressurant Weight		4.6		2.3
F. System Wet Weight		1031.9		424.3

3.5.4 MATERIALS OF CONSTRUCTION.- Except for the ablation material in the TCA's, all internal wetted surfaces are fully compatible with the fluids contained therein. The pressurant and propellant storage tanks are fabricated of titanium alloy and corrosion resistant steel lines are used throughout the system. Components are fabricated of corrosion resistant steel except in certain locations (e.g., springs, valve seats, bladders and solenoid coils) where functional requirements dictate the use of other more desirable materials of compatibility appropriate to their environment.

3.5.5 ASSEMBLY.- The components of the system are assembled into groups as shown in Figures 2 and 3.

3.5.6 INTERCHANGEABILITY.- System components which perform identical functions are directly and completely interchangeable with one another.

3.5.7 COMPONENT LIFE.- All components are designed for a minimum of fifteen missions with an operating life comparable to at least one mission, with the following exceptions:

A. Cartridge-actuated valves have a one-shot life with a probability of satisfactory operation of at least 0.9999. REV

B. Expulsion tank bladders have a minimum life of six complete expulsions under service conditions.

C. Thrust Chamber Assembly life consists of operation, either continuous or in pulsing mode, wherein pulse frequency and duration is randomly distributed between 0 and 6 pulses per second and 0.010 and 3.75 seconds per pulse, respectively, for the attitude control TCA's, and 0 to 1 pulse per second and 0.25 and 200 seconds per pulse for the maneuver TCA's. Individual life ratings are:

25 pound Thrust Chamber Assemblies..................270 seconds

85 pound Thrust Chamber Assemblies..................270 seconds

100 pound Thrust Chamber Assemblies.................540 seconds

3.5.8 GROUND CHECKOUT.- Ground checkout consists of leakage measurements and functional checks of all components using helium and nitrogen gases at suitable pressures. Component gas flow rate calibrations are performed and comparisons made with acceptability standards. The manual valves and the ground test connections are used for component checkout. A complete functional checkout of every component can be performed if necessary, including the firing of the TCA's with propellant.

3.6 ENVIRONMENTAL CONDITIONS.- The OAMS functions in accordance with this specification when subjected to any natural combination of the environments shown in Tables I and II.

3.7 STRUCTURAL REQUIREMENTS.- All components of the OAMS are designed for the pressures defined in Sections 3.7.1 and 3.7.2. The components also withstand, without permanent deformation, the limit acceleration and shock loads from Tables I and II, the maximum rated thrust of the TCA units, and any loads which may result from the operation of the system. Ultimate design loads at which structural failure shall not occur are 1.36 times limit loads. An additional 1.5 factor is used on any castings in the components. When critical, the ultimate strength provides for a minimum of 1.36 times limit loads combined with the design pressures of Sections 3.7.1 and 3.7.2. The components are considered full (pressurant and propellant). Limit temperatures are shown in Tables I and II, and operating temperatures will be determined by tests. Ultimate heating effects are considered by increasing limit temperatures to 200°F under certain specified conditions. Ultimate design conditions are either ultimate loads or proper combinations thereof with limit temperatures or ultimate heating effects combined with limit loads. REV

3.7.1 PRESSURES AND TEMPERATURES

A. Normal Operating Pressures.- The normal operating pressures for components located upstream of the pressure regulator (including the regulator inlet) are 3000 psig and regulated pressure (280 psig) for components located downstream from the pressure regulator (and including the regulator outlet).

B. Normal Operating Temperature.- The normal operating temperature is 70°F.

C. Design Pressures.- The design pressure for components located upstream of the pressure regulator is 3000 psig. The design pressure for components located downstream from the regulator is 300 psig.

D. Design Temperature.- The design temperature spans the range of +15°F to +160°F.

E. Proof Pressures.- Component proof pressure at 70°F is 150% of the design pressure, except that for the pressurant storage and the propellant tanks it is 167% of the design pressure.

F. Burst Pressures.- Component burst pressure at 70°F is 250% of the design pressure, except that for the pressurant storage and the propellant tanks it is 222% of the design pressure.

3.7.2 TABULATION OF OPERATING, PROOF AND BURST PRESSURES FOR COMPONENTS

Component Class	Normal Operating Pressure (psig)	Design Pressure (psig)	Proof Pressure % of Design Pressure	Proof Pressure (psig)	Minimum Burst Pressure % of Design Pressure	Minimum Burst Pressure (psig)
High Pressure Components	3000	3000	150	4500	250	7500
a) Pneumatic Spheres	3000	3000	167	5010	222	6660
Pressure Regulator						
a) Inlet	3000	3000	150	4500	250	7500
b) Outlet	280	300	150	450	250	750
Regulated Pressure Components	280	300	150	450	250	750
a) Propellant Tanks	280	300	167	500	222	666

NEW

DESIGN ENVIRONMENTAL CONDITIONS FOR ORBIT A

Design Environment \ Equipment Life Phase	Transportation and Prelaunch (Operating and Nonoperating)
Ambient Temperature (2)	✦ 20°F to 160°F (Serviced) & -60°F to 160°F (Unser
Ambient Pressure	15.5 to 1.4 psia
Temperature-Pressure	N.A. (1)
Relative Humidity	15% to 100%
Rain	MIL-E-5272C, Procedure II
Salt Sea Atmosphere	MIL-E-5272C, Procedure I
Sand and Dust	MIL-E-5272C, Procedure I
Fungus (3)	MIL-E-5272C, Procedure I
Shock	N.A. (Prelaunch) and Protected per M.A.C. Report 8757 (Transportation)
Acceleration (4) (5)	N.A. (Prelaunch) and Protected per M.A.C. Report 8757 (Transportation)
Vibration	
Category A (Figure 15) (7)	N.A. (Prelaunch) and Protected per M.A.C. Report 8757 (Transportation)
Category B (Figure 16) (8)	N.A. (Prelaunch) and Protected per M.A.C. Report 8757 (Transportation)
Acoustic Noise	N.A. (Prelaunch) and Protected per M.A.C Report 8757 (Transportation)
Radio Interference	MIL-I-26600
Explosive Atmosphere	Hydrogen Atmosphere (9)

NOTES:

1. N.A. - Not Applicable
2. These are the design extreme temperatures for the propellant tank and distribution system. The combustion chamber is designed for a maximum external temperature of 500°F.
3. Applicable to untested and untreated materials only.
4. Lateral Spacecraft Axes refers to both the pitch and yaw axes as defined for spacecraft control.
5. All shock and accelerati are limit loads. Satis required during and/or a cation, whichever is ap shall tear loose from it shall be contained under loads. Ultimate load is
6. Longitudinal and Lateral

TABLE I

ITUDE AND MANEUVER SYSTEM EQUIPMENT LOCATED IN THE ADAPTER

	Launch (Operating)	Orbit (Operating)
)	+1[illegible] to 160°F	+15°F to 160°F
	15.5 to 10^{-12} psia	10^{-12} psia
	160°F at 15.5 to 10^{-12} psia	160°F at 10^{-12} psia
	15% to 100%	N.A.
	N.A.	N.A.
	N.A.	N.A.
	N.A.	N.A.
	N.A.	N.A.
	N.A.	N.A.
	Longitudinal Spacecraft Axis: 1.g to 7.25g's linearly with time over 326 sec. Lateral Spacecraft Axes: 4.0g's in any direction for 1 sec. (6)	0g
	Curve I	Curve II
	Curve I	Curve II
	155 db Over-all, See Figure 17	N.A.
	MIL-I-26600	MIL-I-26600
	N.A.	N.A.

ı loads in this table
:tory performance is
:er limit load appli-
ıpriate. No equipment
mount and internal parts
ıpplication of ultimate
.36 times limit load.
lo not act simultaneously.

7. Equipment items which are mounted to spacecraft primary structure directly or through intervening structure and/ or are of sufficiently small mass that the mechanical impedance of the spacecraft structure as seen by the equipment installation attach points can be considered effectively infinite.
8. Equipment items or complete system installations of sufficiently large size and mass that the mechanical impedance of the attach points cannot be taken as infinite, and the feeding back mechanism has been given consideration.
9. Equipment will be tested for explosion proofing using a standard commercial butane and air mixture.

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TABLE II

DESIGN ENVIRONMENTAL CONDITIONS FOR ORBIT ATTITUDE AND MANEUVER SYSTEM AND RE-ENTRY C

Design Environment \ Equipment Life Phase	Transportation and Prelaunch (Operating and Nonoperating)	(
Ambient Temperature	20°F to 160°F	0°F to 160°F
Ambient Pressure	23.5 to 15.5 psia	15.5 to 10^{-12}
Temperature-Pressure	N.A. (1)	160°F at 15.5
Relative Humidity	15% to 100%	15% to 100%
Rain	MIL-E-5272C, Procedure II	N.A.
Salt Sea Atmosphere	MIL-E-5272C, Procedure I	N.A.
Sand and Dust	MIL-E-5272C, Procedure I	N.A.
Fungus (2)	MIL-E-5272C, Procedure I	N.A.
Oxygen Atmosphere	100% O_2 at 15.5 psia	100% O_2 at 6.0
Shock (3) (4) (5)	N.A. (Prelaunch) and Protected per M.A.C. Report 8757 (Transportation)	N.A.
Acceleration (3) (4)	N.A. (Prelaunch) and Protected per M.A.C. Report 8757 (Transportation)	Longitudinal 1. g to 7.25 time over 3 Spacecraft A any directio
Vibration		
Equipment Category A (Figure 15) (7)	N.A. (Prelaunch) and Protected per M.A.C. Report 8757 (Transportation)	Curve I
Equipment Category B (Figure 16) (8)	N.A. (Prelaunch) and Protected per M.A.C. Report 8757 (Transportation)	Curve I
Acoustic Noise	N.A. (Prelaunch) and Protected per M.A.C. Report 8757 (Transportation)	135 db Over-al
Radio Interference	MIL-I-26600	MIL-I-26600
Explosive Atmosphere	N.A.	N.A.

NOTES:

1. N.A. - Not applicable.
2. Applicable to untested and untreated materials only.
3. Lateral Spacecraft Axes refers to both the pitch and yaw axes as defined for spacecraft control.
4. All shock and acceleration loads in this table are limit loads. Satisfactory performance is required during and/or after limit load application, whichever is appropriate. No equipment shall tear loose from its mount and internal parts shall be contained under application of ultimate loads. Ultimate load is 1.36 times limit load.
5. Longitudinal and Lateral do not a
6. Longitudinal and Lateral act simu
7. Equipment items which are mounte primary structure directly or thr structure and/or are of sufficien that the mechanical impedance of structure as seen by the equipmen attach points can be considered e infinite.

II

CONTROL SYSTEM EQUIPMENT LOCATED IN THE RE-ENTRY MODULE IN THE PRESSURIZED CABIN

Launch (Operating)	Orbit (Operating)	Re-Entry and Landing (Operating)	Post-Landing (Nonoperating)
°F	0°F to 160°F	200°F	+15°F to 160°F
-12 psia	6.0 to 10^{-12} psia	10^{-12} to 15.5 psia	15.5 psia
5.5 to 10^{-12} psia	160°F at 6.0 to 10^{-12} psia	200°F at 10^{-12} to 15.5 psia over 10 Min.	N.A.
%	50% to 80%	15% to 100%	15% to 100%
	N.A.	N.A.	MIL-E-5272C, Procedure II
	N.A.	N.A.	MIL-E-5272C, Procedure I
	N.A.	N.A.	MIL-E-5272C, Procedure I
	N.A.	N.A.	MIL-E-5272C, Procedure I
6.0 psia	100% O_2 at 6.0 psia	100% O_2 at 6.0 psia	N.A.
	N.A.	See Figure 19(Area II)	15g's in any direction, 11 millisecond duration
al Spacecraft Axis: 7.25 g linearly with r 326 sec. Lateral ft Axes: 4.0g's in ction for 1 sec. (5)	Og	Longitudinal Spacecraft Axis: 15g's, 30 sec. duration. Lateral Spacecraft Axes: 4.5g's, 30 sec. duration (6)	1 g
	Curve II	Curve III	N.A.
	Curve II	Curve III	N.A.
r-al See Figure 18	N.A.	Same as for Launch	N.A.
)	MIL-I-26600	MIL-I-26600	MIL-I-26600
	N.A.	N.A.	N.A.

ɔt act simultaneously.
ɪimultaneously.
ɪted to spacecraft
through intervening
ːiently small mass
of the spacecraft
ɪment installation
ɪd effectively

8. Equipment items or complete system installations of sufficiently large size and mass that the mechanical impedance of the attach points cannot be taken as infinite, and the feedback mechanism has been given consideration.

R
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GEMINI SPACECRAFT VIBRATION SPECTRA

EQUIPMENT CATEGORY A

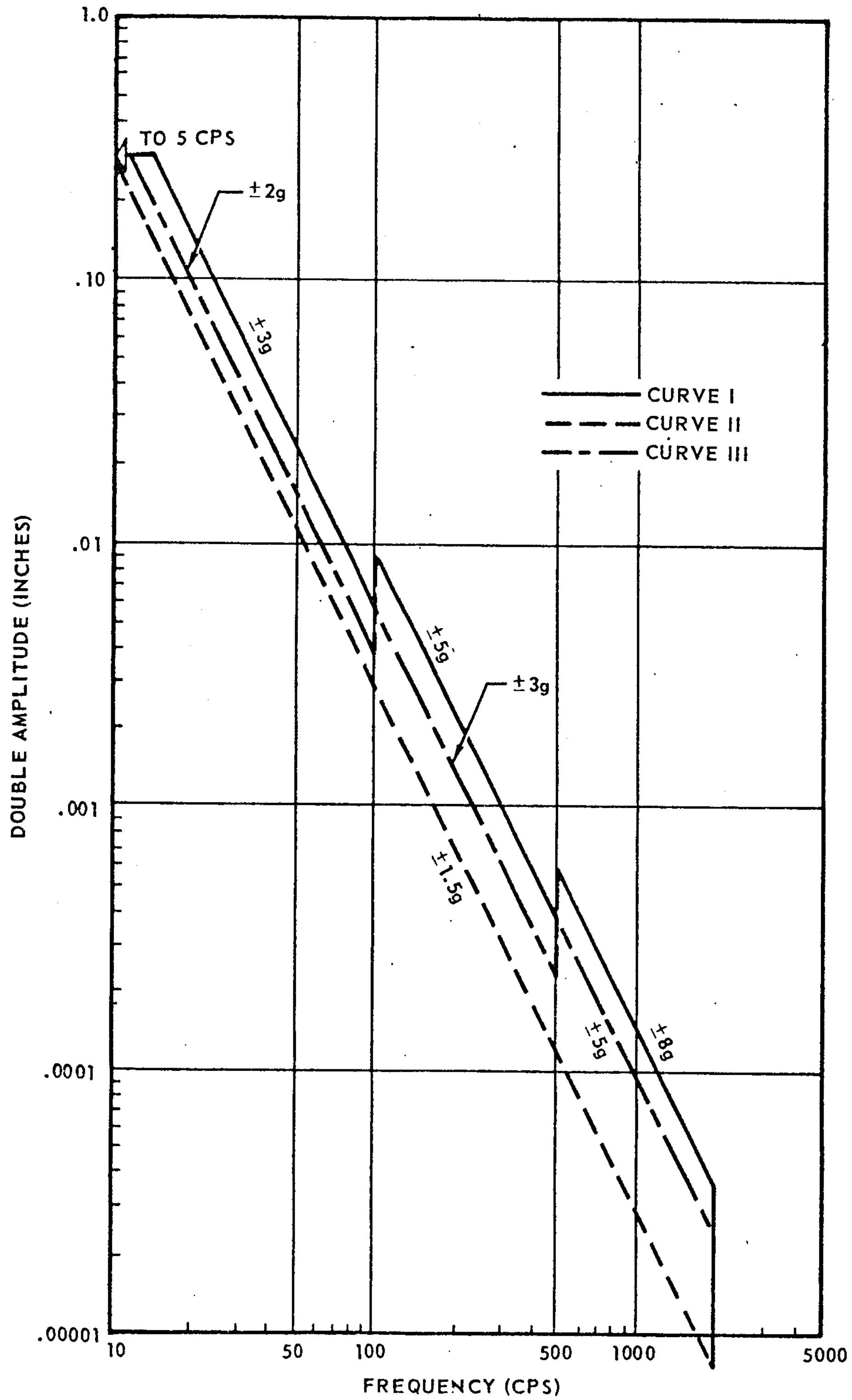


Figure 15

N
E
W

GEMINI SPACECRAFT VIBRATION SPECTRA

EQUIPMENT CATEGORY B

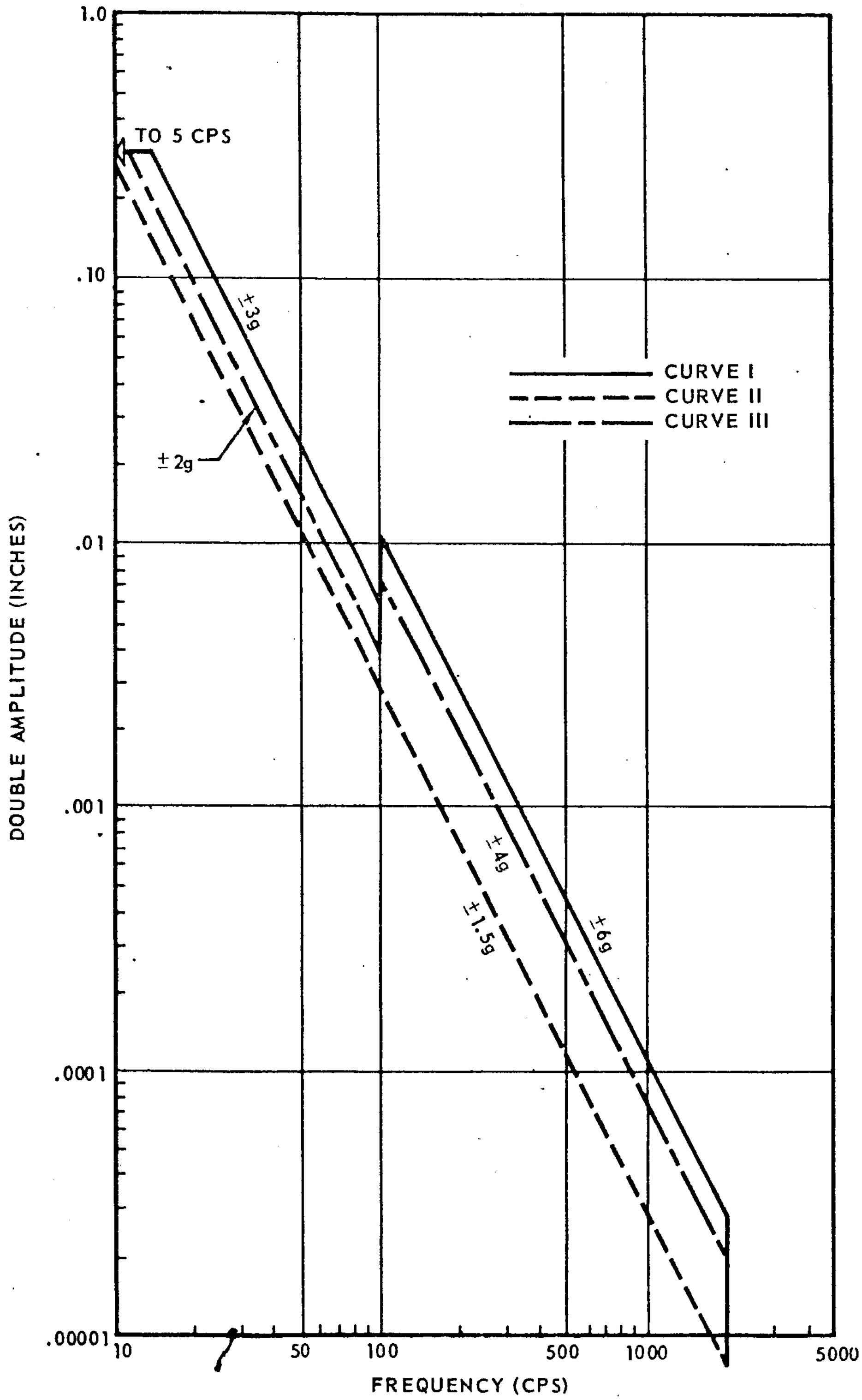


Figure 16

NEW

GEMINI SPACECRAFT ACOUSTIC ENVIRONMENT SPECTRUM

(IN THE ADAPTER)

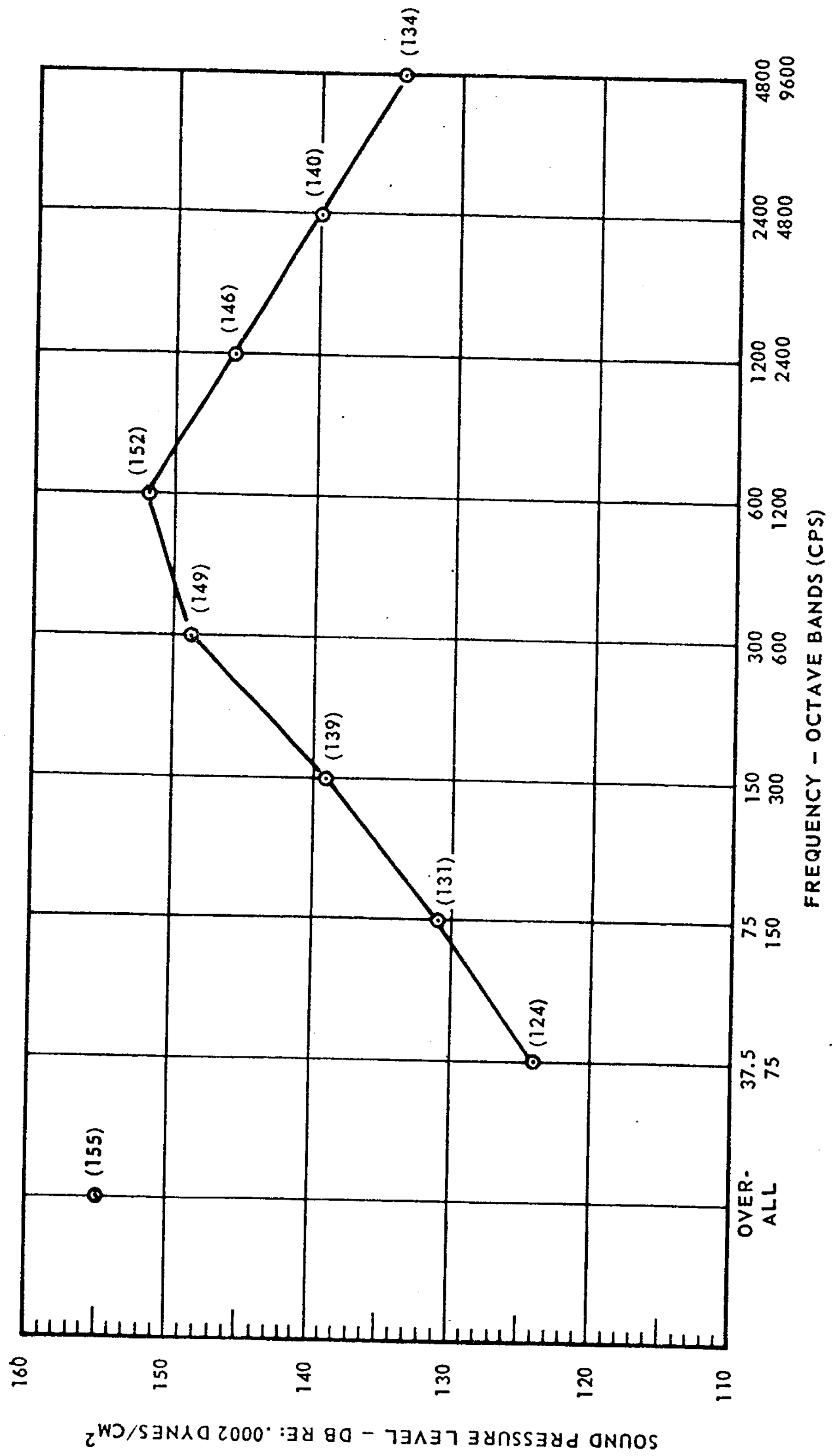


Figure 17

GEMINI SPACECRAFT ACOUSTIC ENVIRONMENT SPECTRUM

(IN THE RE-ENTRY MODULE IN THE PRESSURIZED CABIN)

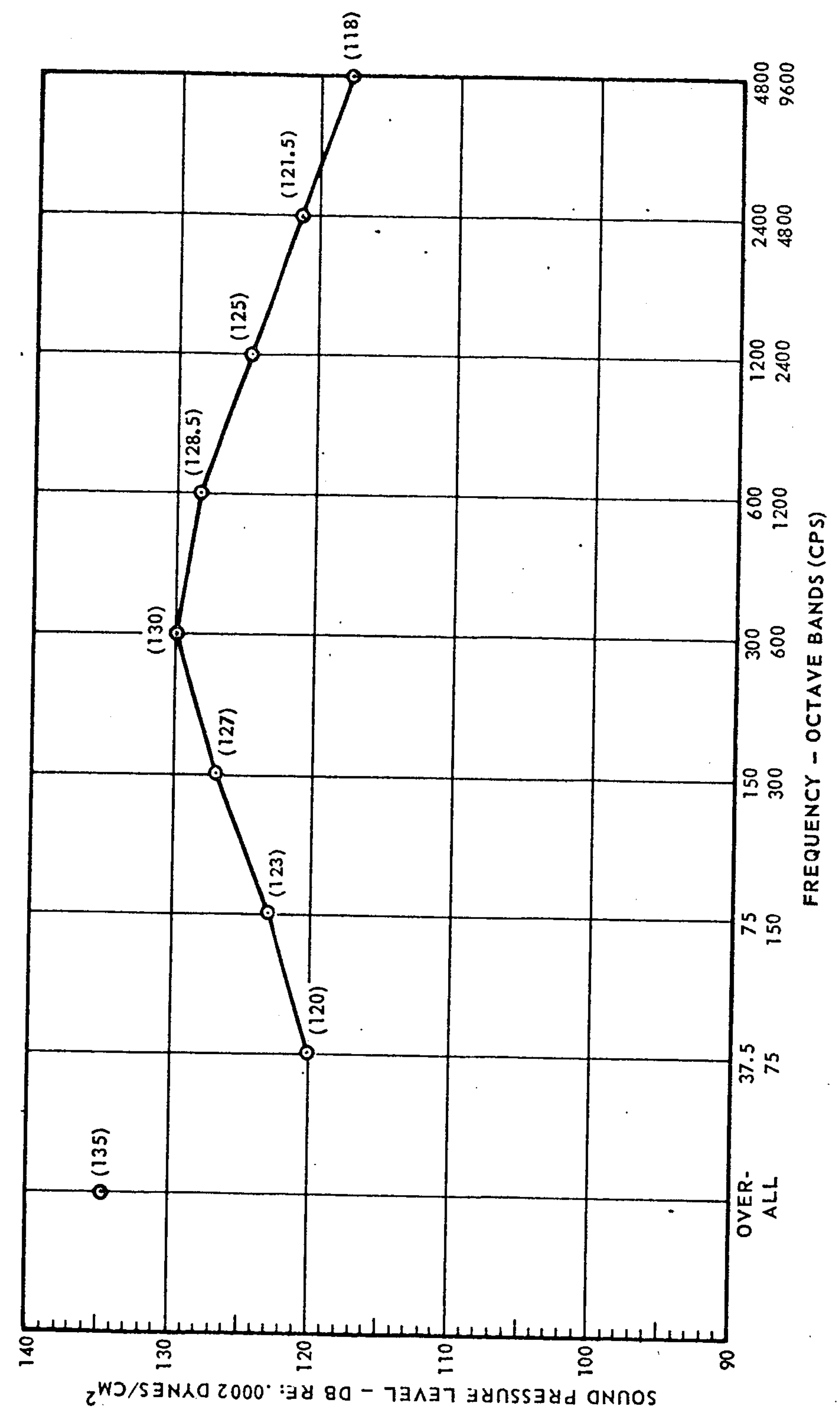


Figure 18

N
E
W

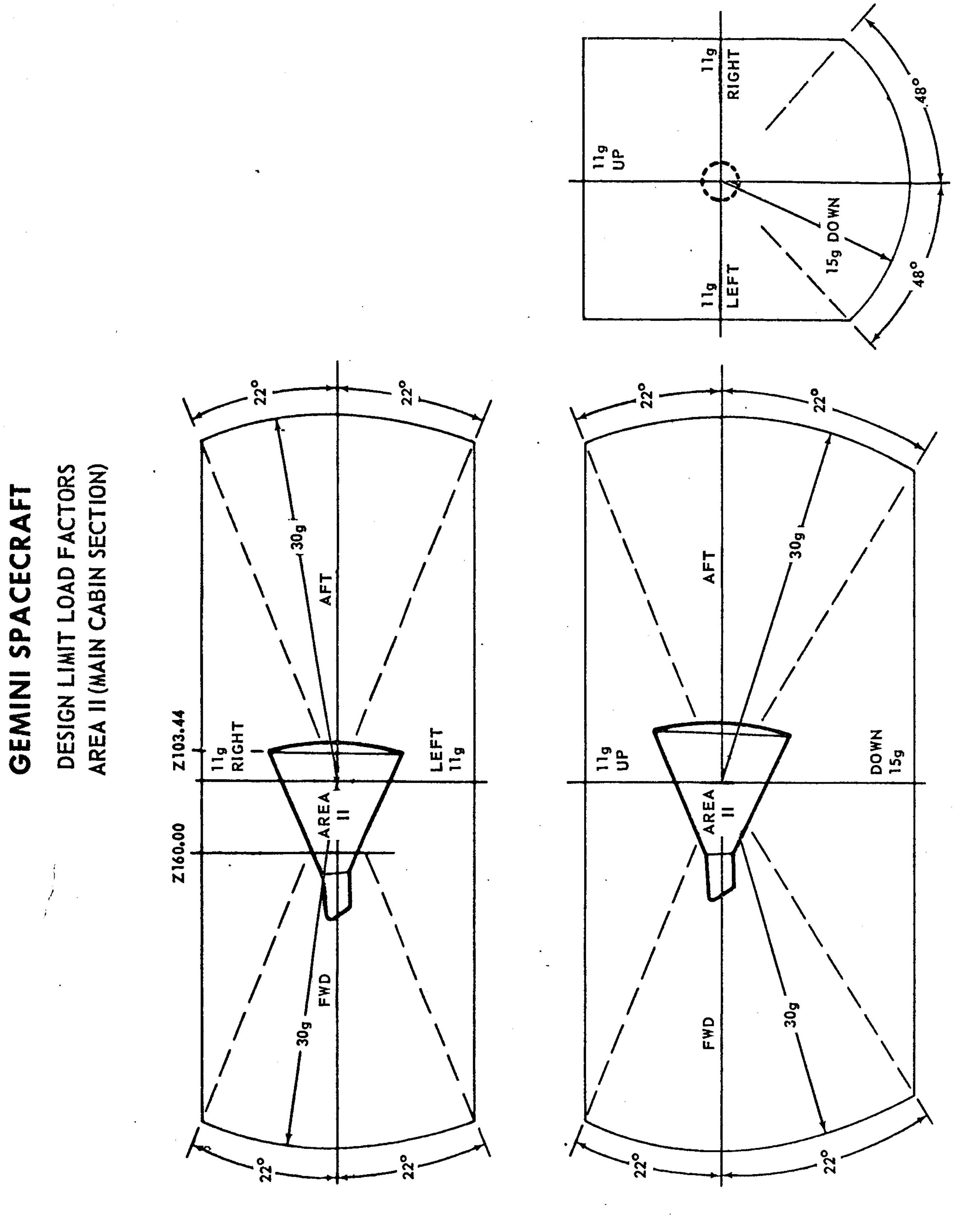

GEMINI SPACECRAFT
DESIGN LIMIT LOAD FACTORS
AREA II (MAIN CABIN SECTION)
Z103.44
Z160.00
11g RIGHT
LEFT 11g
AREA II
AFT
FWD
30g
22°
11g UP
DOWN 15g
11g RIGHT
11g UP
11g LEFT
15g DOWN
48°

Figure 19

4. RETROGRADE ROCKET SYSTEM

4.1 GENERAL.- The retrograde rocket system consists of four solid-propellant rocket motors mounted in the retrograde section of the adapter, symmetrically located about the longitudinal axis of the spacecraft as shown in Figure 20.

A description of two different retrograde rocket systems is contained in this report. The system described in this section will be used in all spacecraft providing that the delivery schedule is compatible with vehicle launch. An alternate rocket motor, which is a modified version of the Thiokol TE-345 rocket, may be required for the earlier spacecraft in the event that these units are not available. A description of the alternate rocket motor is contained in Addendum A.

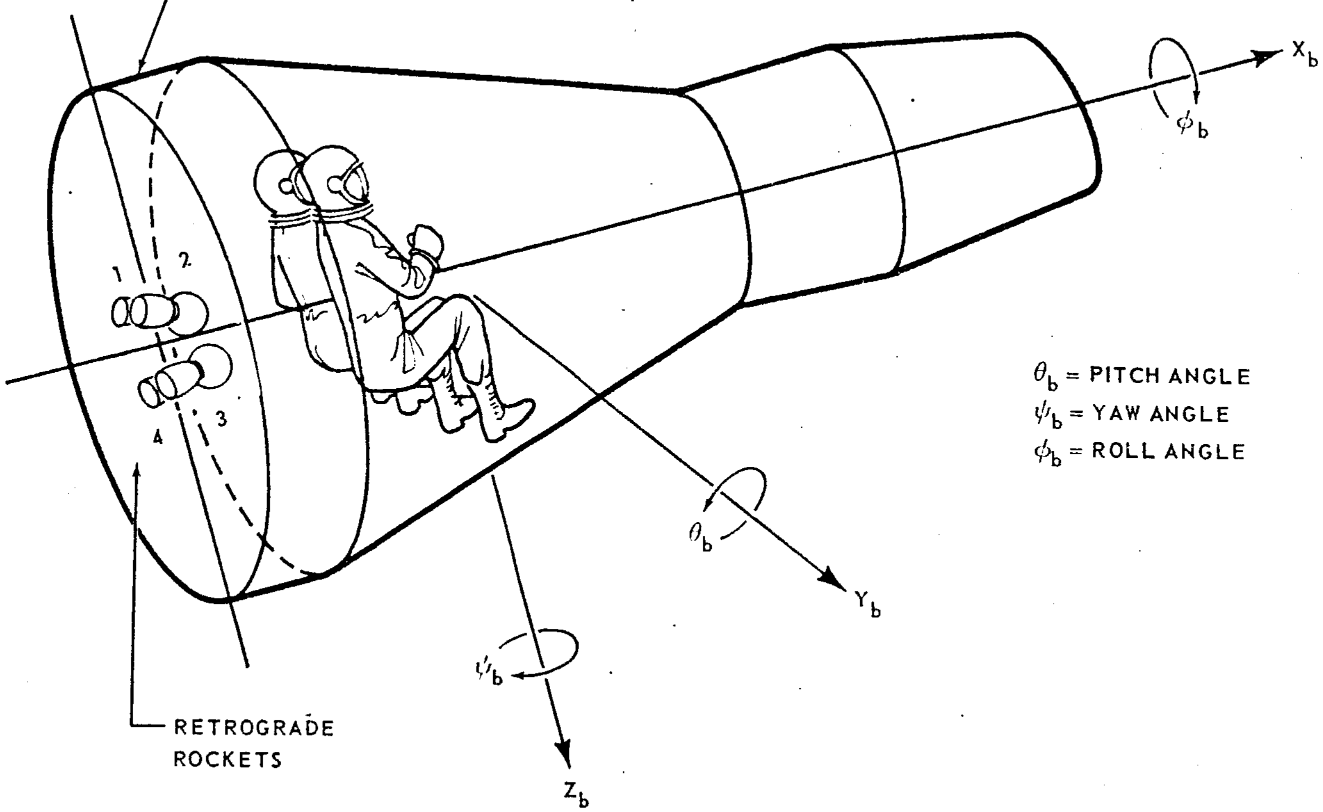
4.2 FUNCTION.- In the normal mission mode of operation, the retrograde rockets are used to impart an impulse to the re-entry module. The resulting velocity decrement permits re-entry into the earth's atmosphere. The retrograde rockets also provide the required spacecraft velocity and separation distance from the launch vehicle in the event of a mission abort. With the system described in this section, an abort can be accomplished at altitudes varying from approximately 80,000 to 300,000 feet. With the system described in Addendum A, an abort can be accomplished at altitudes varying from 110,000 to 300,000 feet. Escape is manually initiated at the discretion of the crew upon indication of booster or spacecraft malfunction.

4.3 OPERATION.- Retrograde rocket operation permission is established by manually arming the retrograde squib firing circuits, after which the firing sequence is controlled either automatically through the time reference system or manually by the crew. Thirty seconds prior to actual retrograde firing (TR-30), the electronic timer illuminates the RETRO ARM indicator/push button on the astronauts' instrument panel. The automatic firing circuit is then manually armed. At TR-0 the electronic timer initiates the retro-fire sequence. The rockets are then fired at $5\frac{1}{2}$ - second intervals. Rocket number 1 is the first to be fired, followed thereafter by number 2, 3 and 4 rockets, respectively (see Figure 20). The rockets are fired in salvo for a mission abort.

4.4 DESIGN REQUIREMENTS

4.4.1 RETROGRADE ROCKET.- The four retrograde rocket motors employed in this system are identical in design and performance, containing a case-bonded, polysulfide/ammonium perchlorate propellant and dual pyrogen igniters in each unit, as shown in Figure 21.

RETROGRADE ROCKET ARRANGEMENT



NOTE:
POSITIVE SENSE OF AXES AND ANGLES INDICATED BY ARROWS

Figure 20

NEW

RETROGRADE ROCKET ASSEMBLY

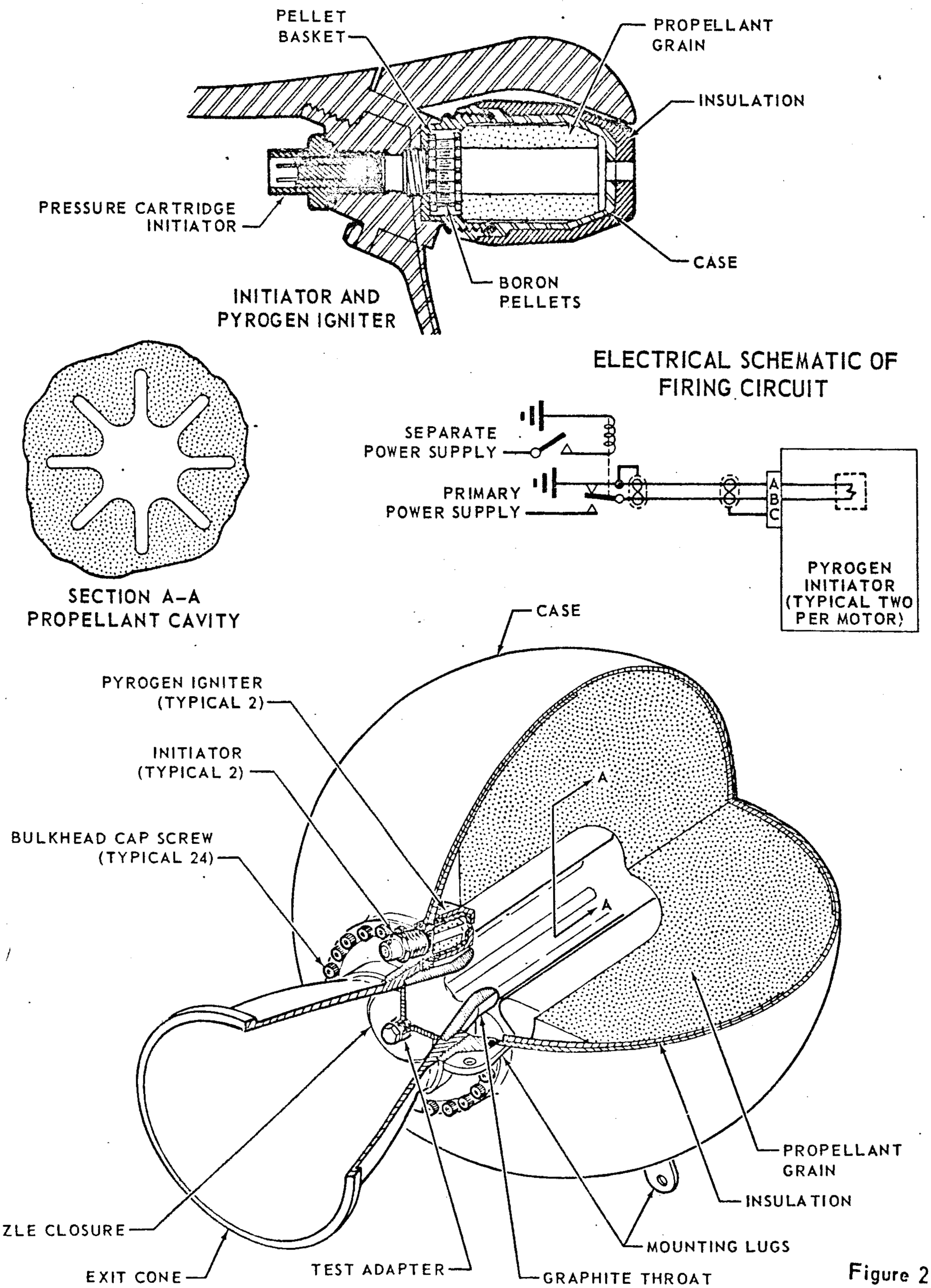


Figure 21

NEW

4.4.1 RETROGRADE ROCKET.- (Continued)

The retrograde rocket is a 12.80 inch diameter spherical motor with a titanium alloy case, a partially-submerged contoured nozzle with a 40:1 expansion ratio, and aft-end-mounted pyrogen igniters with removable pressure cartridge initiators. It is approximately 23.0 inches in over-all length.

Each rocket delivers a total impulse of 13,800 pound-seconds at an average thrust of 2490 pounds over a burning time of 5.44 seconds. These performance ratings are based on a propellant bulk temperature of +60°F and vacuum operation. Rocket performance, weight, and other pertinent design parameters are shown in Figure 22.

The rockets are beam-mounted in the retrograde section of the adapter as shown in Figure 23 and are individually aligned in the adapter prior to adapter/re-entry module mating so as to minimize the eccentricity between the thrust vector and the retrograde weight center-of-gravity.

4.4.1.1 NOZZLE ASSEMBLY AND CASE.- The rocket motor case is a high-strength titanium alloy sphere 12.80 inches in diameter. The case is formed from two hemispherical halves joined together at the equator with a "uniweld" after heat treatment to 190,000 psi ultimate and a minimum yield of 170,000 psi. Each half is formed by forging, then final-machined to the minimum wall thickness as determined by using a factor of 1.4 times the maximum expected pressure at +180°F. NEW

The aft hemisphere incorporates a drilled and tapped flange which mates with the nozzle assembly. The nozzle assembly consists of three components: an expansion cone, a throat insert, and a nozzle bulkhead. Each of the several concepts and materials embodied in the nozzle assembly design have been successfully proven in a number of different solid-propellant rocket motors. The expansion cone is constructed from a vitreous silica-phenolic resin that is compression molded. This lightweight material will ablate slightly in the supersonic region, as evidenced from actual static tests. However, when used with a non-eroding throat, the ablation is quite uniform and small. It has an expansion ratio of 40 to 1.

The throat insert is machined from a high density graphite and is bonded into the expansion cone. The insert is separated from the titanium nozzle supporting structure of the aft bulkhead by the plastic of the exit cone and the case insulation. This construction reduces the heat transfer to the structure supporting the nozzle, thereby preventing loss of structural integrity. The throat will be recessed to permit a reduced length.

RETROGRADE ROCKET PERFORMANCE WEIGHT, AND DESIGN PARAMETERS

PERFORMANCE AT 60°F AND VACUUM OPERATION

AVERAGE PRESSURE OVER BURNING TIME (PSIA)	846
AVERAGE THRUST OVER BURNING TIME (LB.)	2,490
TOTAL IMPULSE OVER ACTION TIME (LB.-SEC.)	13,800
IGNITION TIME; TIEM TO 75% P_{MAX} (MILLISECONDS)	100 (MAX.)
BURNING TIME (SECONDS)	5.44
ACTION TIME (SECONDS)	5.80
SPECIFIC IMPULSE(LB.-SEC./LB.)	254

WEIGHTS (LB.)

	65.0 (NOM.)
	66.0 (MAX.)

NOZZLE DESIGN

EXPANSION RATIO	40:1
EXIT AREA ($IN.^2$)	85.2
THROAT AREA ($IN.^2$)	2.13

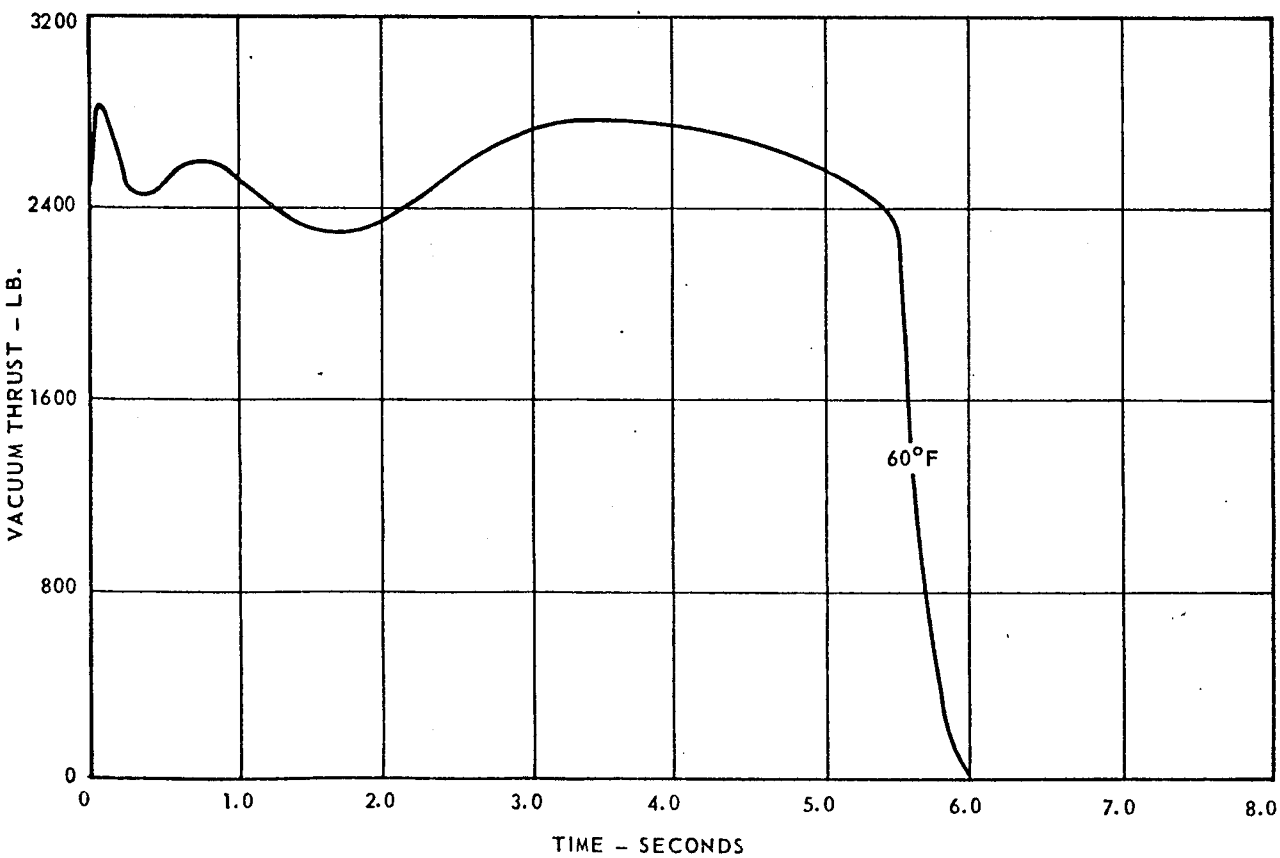


Figure 22

NEW

RETROGRADE ROCKET SYSTEM INSTALLATION

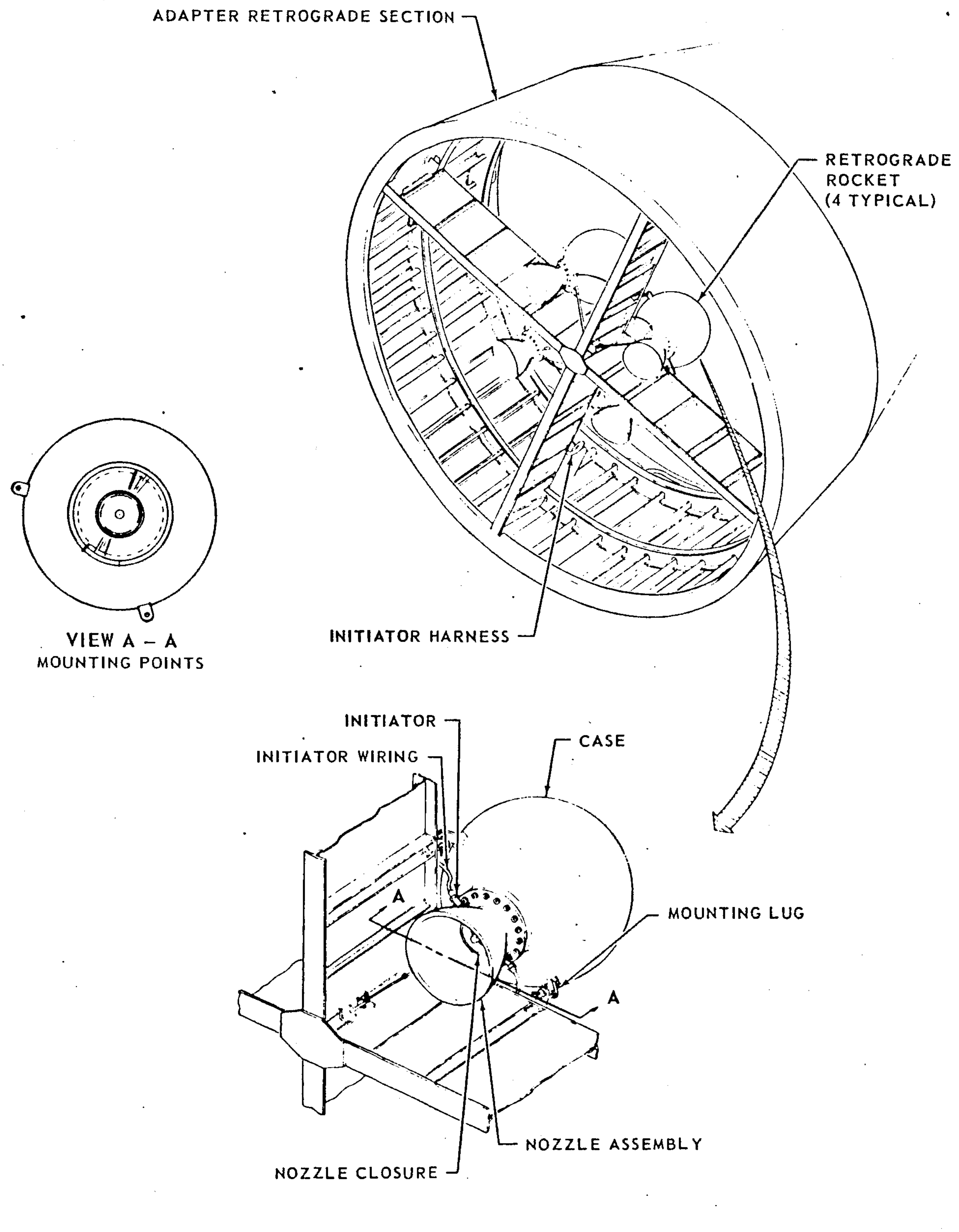


Figure 23

NEW

4.4.1.1 NOZZLE ASSEMBLY AND CASE.- (Continued)

A nozzle closure is sandwiched between the insert and the expansion cone interface. This closure has a shear groove that permits the closure to be ejected at a predetermined pressure level. The closure contains a fitting to permit pressure checking of the motor as required.

The aft bulkhead is machined from a forging of the same titanium alloy as the case. It provides a threaded interface into which the expansion cone is fitted. The bulkhead is bolted to the motor case and an O-ring is used to effect proper sealing of the chamber during motor operation. A lug is provided for the purpose of motor installation and alignment. Insulation material is applied to the case interior by a bag-molding technique.

4.4.1.2 SOLID PROPELLANT.- The propellant used in the rocket motor is a fully developed polysulfide-ammonium perchlorate system. The propellant formulation used provides a propellant grain which is extremely reliable over the required temperature range. The grain is cast and cured in the motor chamber and has an internal burning eight-pointed star configuration.

4.4.1.3 IGNITION SYSTEM.- Two independent and redundant pyrogen type igniters are used in each motor, mounted on the aft end of the motor. Each pyrogen is essentially a small, internal burning, solid-propellant rocket motor with its own initiator and igniter pellets. The motor is prepared for firing by inserting a pressure cartridge initiator into each pyrogen igniter. The initiator ignites the pyrogen propellant which discharges its exhaust gases into the motor cavity, providing the pressure and thermal energy to ignite the surface of the motor propellant grain in a smooth, reproducible manner. The pyrogen provides a sustained discharge for approximately 200 milliseconds to provide a large factor of safety and to assure a high level of confidence in reliable vacuum ignition. NEW

The case and cap are machined from a titanium alloy. The case is threaded at one end to permit attachment of the pyrogen head caps. It is 1.4 inches in diameter and has an over-all length of 1.6 inches and a throat diameter of 0.19 inches. An insulation sleeve made from a silica fabric, reinforced with a phenolic material, protects the pyrogen assembly during motor operation. It is bonded in place to the exterior of the case. The propellant is cast into a paper phenolic tube and, after it is cured, is inserted into the interior of the case.

The pyrogen employs a booster charge consisting of boron/potassium nitrate pellets. These pellets are constrained in a container assembly composed of a stainless steel body, type 303, and a perforated nickel diaphragm to prevent ignition debris from blocking the nozzle.

4.4.1.3 IGNITION SYSTEM.- (Continued)

The propellant used in the pyrogen is a fully developed, polysulfide/ammonium perchlorate system designated TP-L-8035, which has been widely employed as a pyrogen propellant in a number of solid-propellant rockets.

The initiator is a small pressure cartridge that is threaded into the pyrogen bulkhead assembly at time of arming of the motor. Each initiator contains a bridgewire system capable of withstanding a one amp, one watt current/power input for five minutes without firing and is capable of firing with the current limited to four amperes. A firing lead cable is connected to a Bendix PT type receptacle incorporated in each initiator. The design is such that if the electrical power to one initiator is interrupted, the other is adequate to ignite the motor.

4.5 ENVIRONMENTAL AND LOAD REQUIREMENTS

NEW

4.5.1 ENVIRONMENTAL CONDITIONS.- The rocket motor and packaged initiator (handling and storage) or installed initiator (prelaunch and launch) do not suffer any detrimental effects during and after exposure to extreme temperature, rain, salt spray, sand and dust, and humidity as defined by Table III. Only nonnutrient materials are used in the construction of the rocket motor and the components thereof.

Materials used in the construction of the unit that are subject to deterioration when exposed to climatic and environmental conditions likely to occur under the conditions specified in Table III are protected against deterioration in a manner that will in no way prevent compliance with required motor performance. Protective coatings that will crack, chip, or scale with age or extremes of climate and environmental conditions are not used.

The unit is designed for storage and operation at relative humidities up to 100 per cent, including condensation due to temperature change.

TABLE III
DESIGN ENVIRONMENTAL CONDITIONS FOR
RETROGRADE ROCKET SYSTEM EQUIPMENT LOCATED IN THE ADAPTER

Design Environment \ Equipment Life Phase	Prelaunch	Launch	Orbit
Ambient Temperature	-20°F to 160°F (2).	-20°F to 180°F (2)(3).	-20°F to 180°F (2)(3).
Ambient Pressure	15.5 to 1.4 psia.	15.5 to 0 psia (2); 1.4 to 0 psia (3).	0 psia (2)(3).
Relative Humidity	15% to 100%	15% to 100%	N.A. (1).
Salt Sea Atmosphere	Protected for 50 hrs in Salt Sea Atmosphere.	N.A.	N.A.
Sand and Dust	Protected for 50 hrs.	N.A.	See Note (4).
Fungus	Protected (5).	N.A.	N.A.
Shock	15 g's, 11 ms. in any direction (6)(7)(8).	N.A.	N.A.
Acceleration	$\pm$6 g's steady state all three axes (6)(7)(8).	1 g longitudinal increasing to 7.25 g's in 326 sec. or lateral load factor 4.0 g's in any direction (6)(7).	.60 g's for 22 sec. at an angle of 16° with the centerline of the motor chamber (3)(6)(7).
Vibration	Protected.	Curve I of Figure 15.	Curve II of Figure 15.
Acoustic Noise	Protected.	155 db. over-all, see Figure 17.	N.A.
Radio Interference	Protected.	Protected.	Protected.
Radiation	N.A.	N.A.	See Note (9).

1. N.A. - Not Applicable.
2. Nonoperating (prelaunch soak temperature).
3. Operating.
4. Seller to comment on the effects of meteoroid dust.
5. Only non-nutrient materials are used in the construction of the rocket motor and the components thereof.
6. The component shall be operable over the limit loads shown; however, for strength purposes, it shall be designed for 1.36 times the limit loads.
7. See Figure 24 for direction of positive longitudinal acceleration (Q direction).
8. These loads shall be applied to packaged motors.
9. To be commented on by Seller.

4.5.1.1 OPERATING REGIMES

4.5.1.1.1 ALTITUDES AND TEMPERATURES.- The rocket motor ignites and operates satisfactorily throughout the ambient pressure range of 15.5 to 0 psia and as follows:

A. Static Exposure - The rocket motor performs satisfactorily after static exposure to a minimum ambient temperature environment of +180°F for a period long enough to condition the entire mass of the engine to +180°F and after exposure to a maximum temperature environment of -20°F for a period long enough to condition the entire mass of the motor to -20°F.

B. Flight Operation - The rocket motor ignites and performs satisfactorily, exhausting to vacuum conditions.

C. Temperature Gradients - The rocket motor performs safely and consistently with the thermal condition of the grain after exposure to a minimum ambient temperature of +180°F for a period long enough to condition the entire mass of the motor to +180°F and fired after exposure to a maximum ambient temperature of -20°F until the maximum temperature gradient exists within the propellant grain. It also performs satisfactorily when conditioned to a maximum temperature of -20°F and then fired after exposure to a minimum ambient temperature of +180°F until the maximum temperature gradient exists in the propellant grain.

4.5.1.2 STORAGE TEMPERATURE RANGE AND ATTITUDE.- The rocket motor and packaged igniter under field storage conditions do not suffer any detrimental effects when exposed to the prelaunch temperature range as presented in Table III and when stored in any attitude. The total accumulated storage time above +140°F will not exceed two weeks.

4.5.1.3 LIMITING EXPOSURE TIME.- The rocket motor operates within specification limits after exposure to a temperature varying from -20°F to +180°F and a vacuum environment for a period not less than fourteen days.

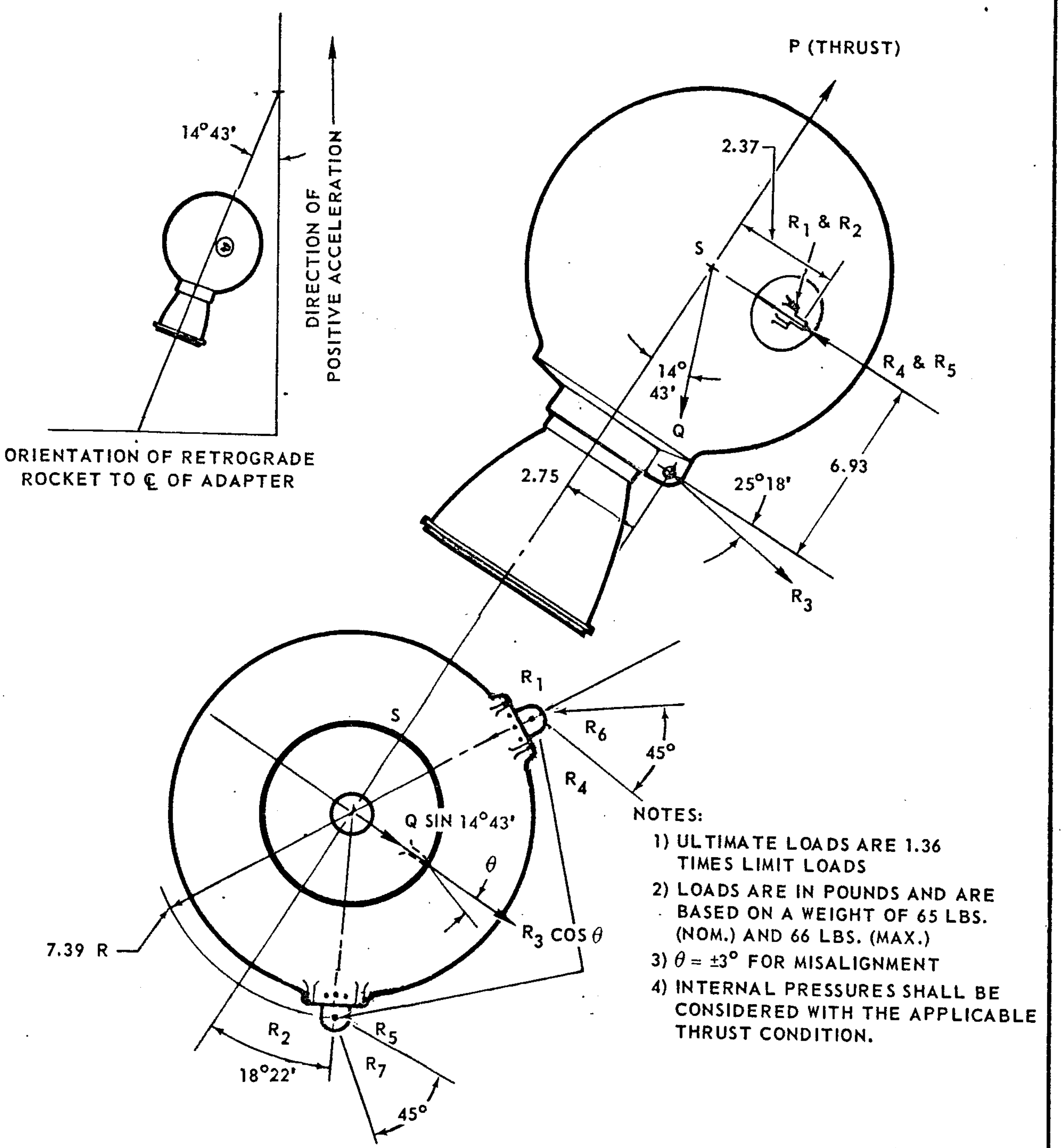
4.5.1.4 VIBRATION.- The rocket motor, with installed igniters, is capable of withstanding without deleterious effects the vibrations as presented in Table III.

4.5.1.5 DROP.- The packaged rocket motor with installed igniters and packaged igniter initiators will perform satisfactorily after being subjected to a four foot drop onto solid reinforced concrete.

4.5.1.6 ACOUSTIC NOISE.- The rocket motor and installed igniter are capable of withstanding acoustic noise as specified in Table III without deleterious effects.

4.6 STRUCTURAL REQUIREMENTS.- The rocket motor and its supports are capable of withstanding without permanent deformation the forces resulting from the loads specified in Table III and Figure 24. For design purposes, the ultimate strength provides for a minimum of 1.36 times the forces resulting from the loads specified in Table III and Figure 24. The proof and burst pressure limits of the thrust chamber exceed the maximum pressure based on either the maximum ignition pressure or the maximum chamber pressure at +180°F, whichever is larger, by factors of 1.1 and 1.4, respectively. Temperature effects shall be considered. As an additional condition on all inert hardware, these temperatures shall be increased 100°F and combined with limit loads (ultimate temperature with limit load condition).

LIMIT LOADS FOR RETROGRADE ROCKET



NOTES:

1) ULTIMATE LOADS ARE 1.36 TIMES LIMIT LOADS
2) LOADS ARE IN POUNDS AND ARE BASED ON A WEIGHT OF 65 LBS. (NOM.) AND 66 LBS. (MAX.)
3) $\theta = \pm 3°$ FOR MISALIGNMENT
4) INTERNAL PRESSURES SHALL BE CONSIDERED WITH THE APPLICABLE THRUST CONDITION.

CONDITION	P	Q	S	R_1 & R_2	R_3	R_4	R_5	R_6	R_7
MAX. THRUST	3740	0	0	1560	1450	927	927	0	0
LAUNCH 7.25 g's	0	478	0	−193	−180	−30	−30	0	0
ABORT 4.0 g's	0	0	264	0	0	−62	62	125	−125

Figure 24

N
E
W

5. RE-ENTRY CONTROL SYSTEM

5.1 GENERAL.- The Re-entry Control System (RCS) is a liquid bipropellant rocket engine propulsion system. The re-entry module carries two of these systems, each one consisting of eight fixed-mount TCA's operating on storable hypergolic propellants supplied by a cold gas pressurized positive expulsion feed system. Complete redundancy is achieved by simultaneous operation of these two completely separate systems. The sixteen TCA's are arranged in the re-entry module as shown in Figure 1.

5.2 FUNCTION.- The two systems, in conjunction with the Attitude Control and Maneuver Electronics (ACME), various sensing devices and the attitude hand controller and foot pedals, are normally used to provide attitude control of the re-entry module from retrograde to deployment of the drogue chute or paraglider, subsequent to the jettisoning of the OAMS.

The two systems respond to electrical signals from the Attitude Control Electronics (ACE) which is a part of ACME or from the attitude hand controller and foot pedals. In response to the electrical signals, the systems produce rocket thrust forces to control the attitude of the vehicle. In the event of failure of one system, the remaining system has the impulse capacity and thrust to guarantee attitude control during retrograde and stabilization for safe re-entry, although touchdown control accuracy may be lessened.

Attitude is controlled automatically by the ACME or manually by the crew either directly or through the ACME. Control by the crew in pitch and roll is accomplished with the attitude hand controller and in yaw with the foot pedals (a detailed discussion of the guidance and control modes of operation is contained in M.A.C. Report 8637).

Pitch, roll, and yaw torques are obtained by selectively firing pairs of TCA's. Each TCA has a nominal thrust output of 25 pounds.

5.3 DESCRIPTION AND OPERATION.- The components in each system are arrayed as shown schematically in Figure 25. Only one system is being shown since both are identical. Both systems are installed as shown in Figure 26. In general, system operation may be described as follows. Cold gas is stored under pressure in the pressurant storage tank and held therein by a normally closed cartridge-actuated valve. When the system is to be activated, the cartridge valve is opened and the pressurant flows to the pressure regulator. The gas pressure is reduced at the regulator to a preset value and this regulated pressure is imposed upon each of the propellant tanks to pressurize the propellants. These tanks are of the flexible collapsing bladder type for positive expulsion of the propellants in the gravity-free environment of

R
E
V

RE-ENTRY CONTROL SYSTEM SCHEMATIC

PRESSURANT GROUP

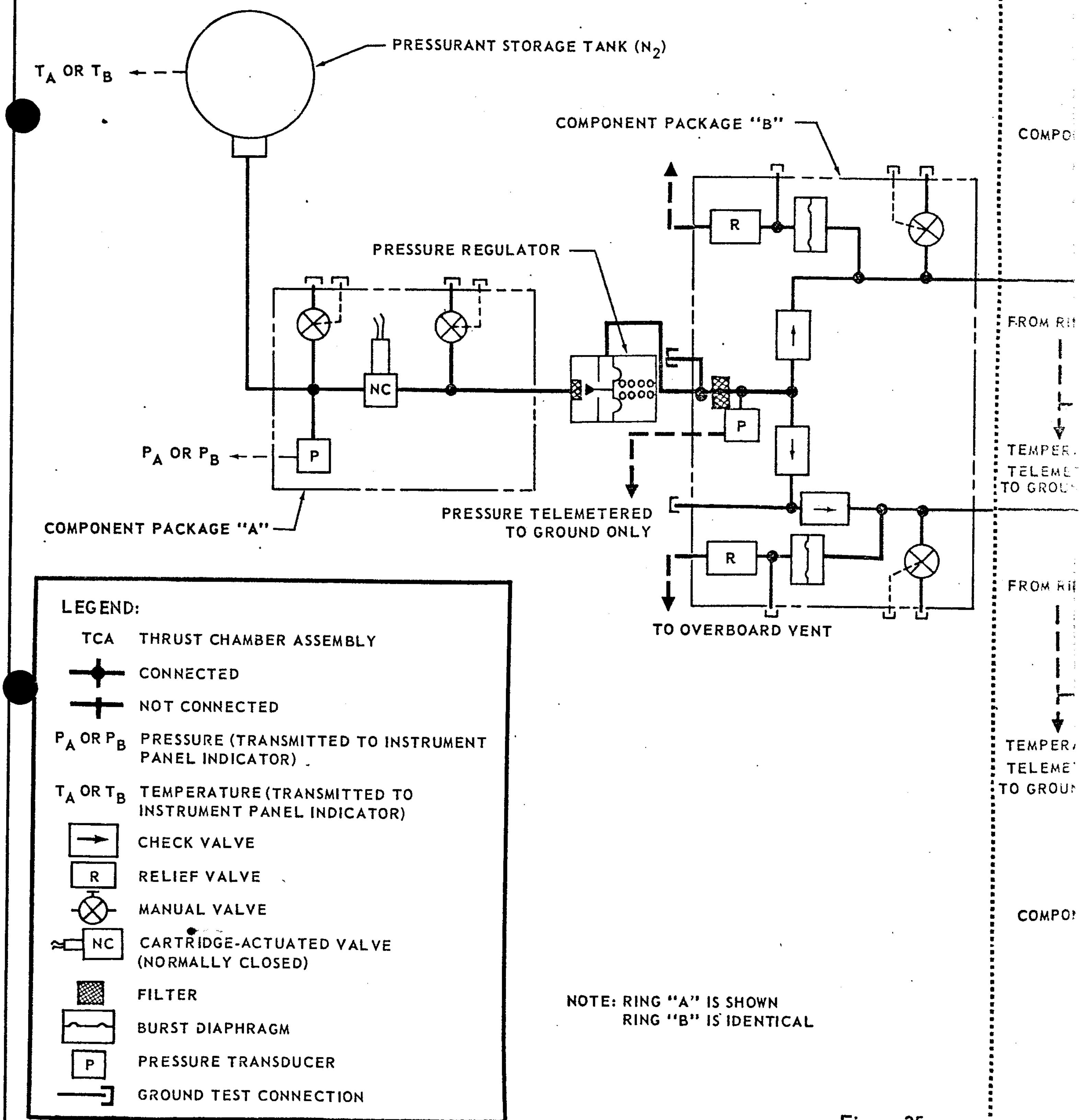
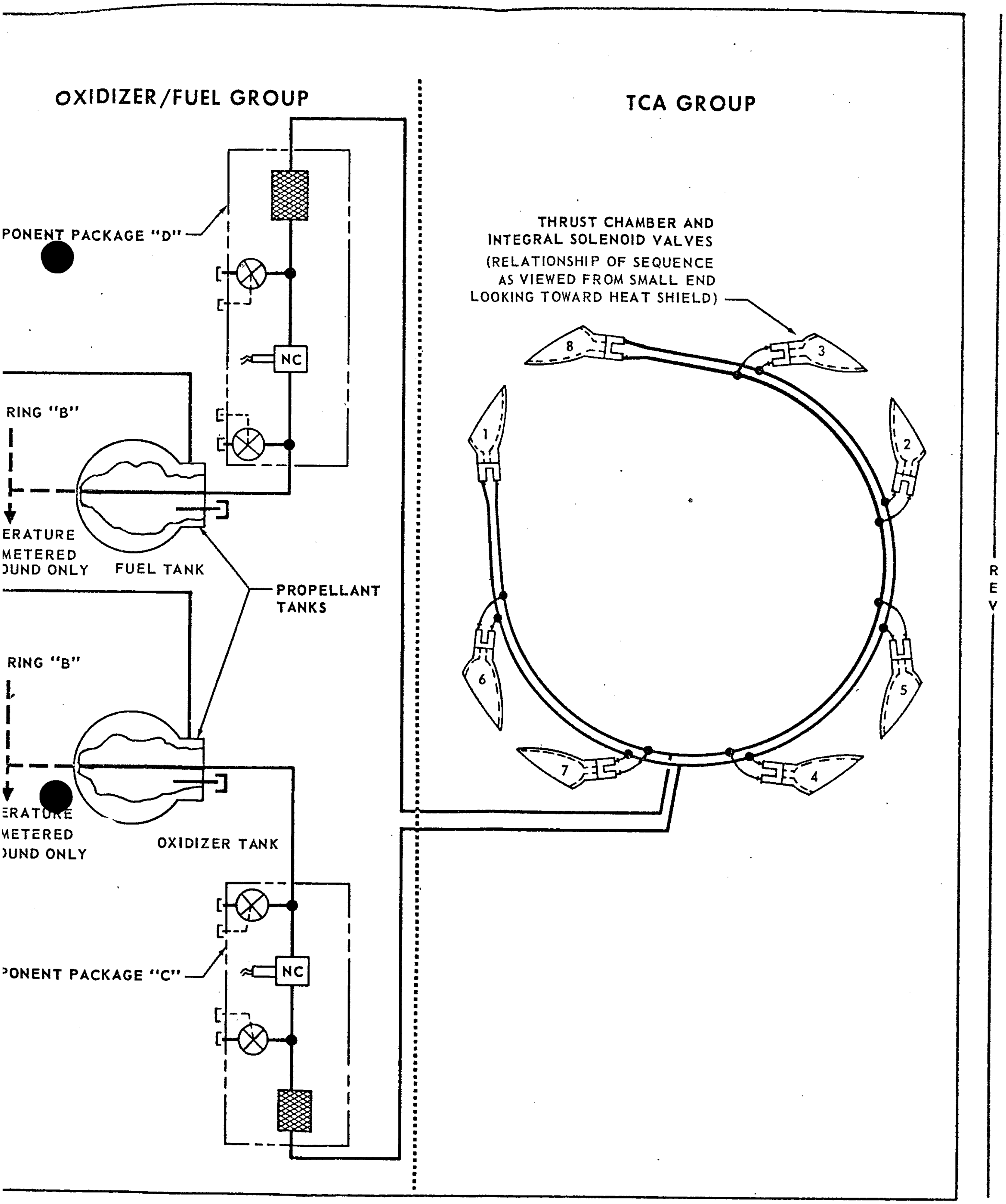
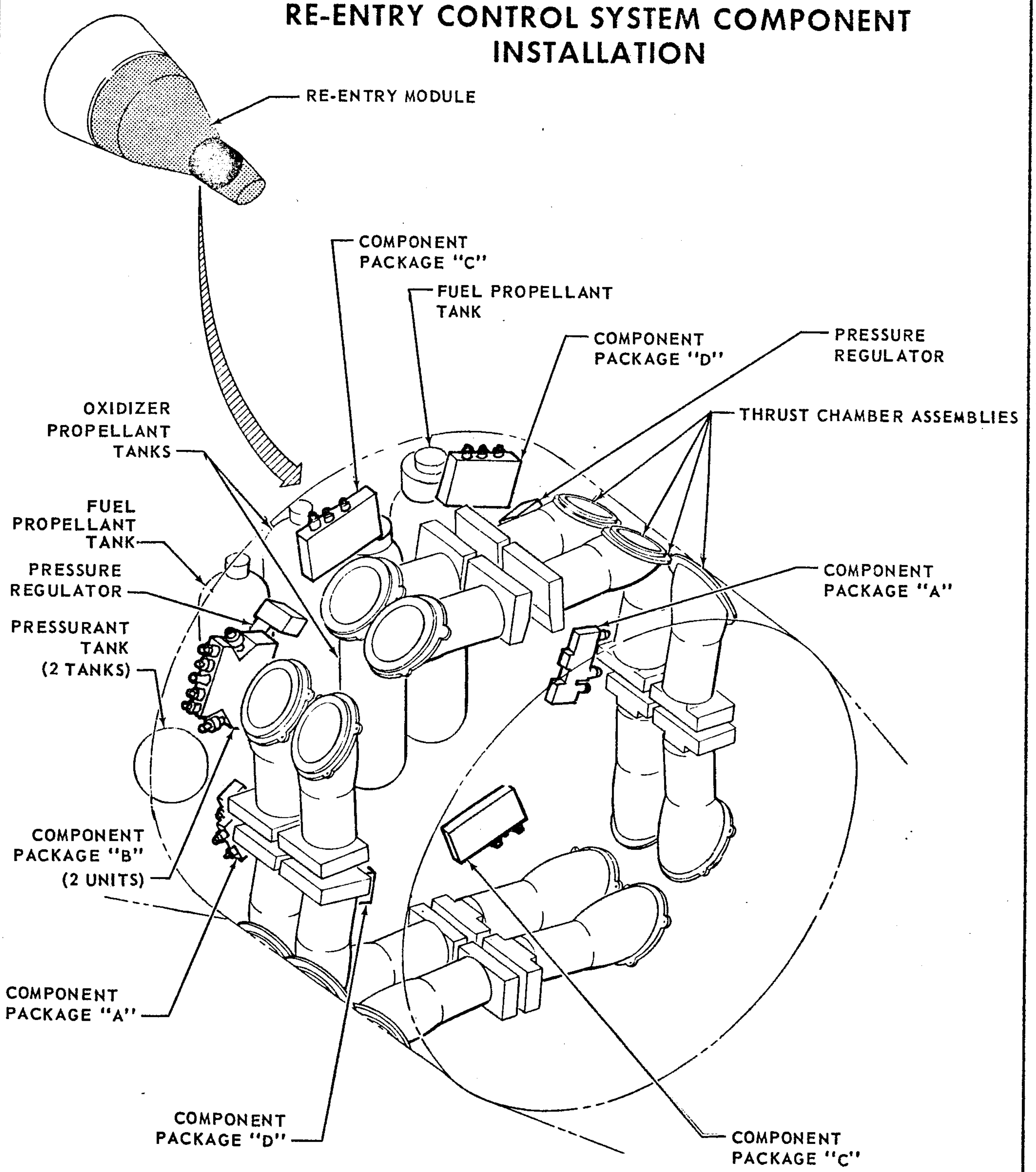


Figure 25



OXIDIZER/FUEL GROUP
TCA GROUP
PONENT PACKAGE "D"
THRUST CHAMBER AND
INTEGRAL SOLENOID VALVES
(RELATIONSHIP OF SEQUENCE
AS VIEWED FROM SMALL END
LOOKING TOWARD HEAT SHIELD)
NC
RING "B"
ERATURE
METERED
UND ONLY
FUEL TANK
PROPELLANT
TANKS
RING "B"
ERATURE
METERED
UND ONLY
OXIDIZER TANK
PONENT PACKAGE "C"
NC
1
2
3
4
5
6
7
8
R
E
V

RE-ENTRY CONTROL SYSTEM COMPONENT INSTALLATION



RE-ENTRY CONTROL SYSTEM SECTION

Figure 26

NEW

5.3 DESCRIPTION AND OPERATION.- (Continued)

space. Simultaneously with the firing of the above mentioned valve, similar valves located downstream from the propellant tanks are opened. The system, with valves open and propellants pressurized, is ready for a firing command. The firing command is received at the thrust chamber propellant valves which open in response, permitting propellant flow to the thrust chamber. The simultaneous introduction of both propellants to the thrust chamber precipitates hypergolic ignition, combustion, and the generation of thrust.

As shown on Figure 25, parts of the two systems are designed on a modular basis, with the modules consisting of several components conveniently and compactly arranged to reduce weight, eliminate leaks, and facilitate the installation, testing, and servicing of the system. There are five such modules: component packages "A", "B", "C", and "D", and the TCA's. In addition, there are the pressurant storage tank, pressure regulator, and propellant tanks.

The components are divided into three main groups: a pressurization group, oxidizer and fuel groups, and TCA group. The pressurization group consists of a pressurant storage tank, component packages "A" and "B", and a pressure regulator. The oxidizer and fuel groups are similar, consisting of propellant tanks and component packages "C" and "D". Each TCA in the TCA group contains propellant valves, injectors, and thrust chambers.

The arrangement and function of the RCS components comprising these groups are essentially the same as those for comparable components in the OAMS, with the difference being that component package "E", the propellant supply on-off valves, and the propellant line guillotines are not included in the RCS and pressure regulation is accomplished only by the regulator. Component packages "A" and "B" and the regulator are the same parts as those in the OAMS while component packages "C" and "D" are scaled down versions of the same parts in the OAMS. A detailed description of these components is contained in the following paragraphs.

The pressurant storage tank is an all-welded, spherical tank. Nitrogen gas is stored in the tank at a nominal storage pressure of 3000 psig. The tank is 7.25 inches in outside diameter and has an internal volume of 185.0 cubic inches.

Component package "A" consists of a pressure transducer, a normally closed cartridge-actuated valve, and two manual valves (Figure 5). The pressure transducer is used to monitor the pressure of the stored high pressure gas. The cartridge valve is used to isolate the pressurant from the remainder of the system prior to system activation. The manual valve upstream of the cartridge valve is used for filling, draining, and purging of the pressurant while the manual valve downstream from the cartridge valve is used during ground checkout of the pressure regulator.

5.3 DESCRIPTION AND OPERATION.- (Continued

The pressure regulator is of the single-stage, conventional mechanical-pneumatic type (Figure 7). A 2-micron inlet filter is used to reduce the contaminants in the gas to an acceptable level, thereby increasing the reliability of the regulator. The nominal pressure setting for regulation is 280 psig.

Component package "B" consists of a pressure transducer, relief valves, burst diaphragms, check valves, manual valves, and ground test connections (Figure 9). The pressure transducer is used to monitor the regulated gas pressure. The relief valves and burst diaphragms are used in conjunction with the regulator to control the regulated gas pressure. The burst diaphragms are used to provide assured zero leakage (until activated) pressure relief devices. In the event of failure of the pressure regulator to reduce the supply pressure sufficiently or excessive temperature cycling, the burst diaphragms will rupture and permit jettisoning of the pressurant gas through the pressure relief vent valves, thereby affording overpressure protection for the other system components. If the burst diaphragms were the sole protective element, a single actuation would result in venting of the total supply of pressure. However, the relief valves avoid this and restrict the venting to that required to correct conditions of a transient type and keep the system pressure at a safe level (i.e., if the regulation failure is momentary in nature, the relief valves reseat and permit normal system operation thereafter). Such a situation can occur in the event of an abnormal thermal cycle coupled with a low rate of propellant consumption. A check valve is provided upstream of the fuel propellant tank to prevent backflow of fuel into the gas system, should the expulsion bladder fail. Check valves are provided upstream of the oxidizer propellant tank to prevent backflow of oxidizer vapor into the gas system. Two are used for double protection against oxidizer vapor which will permeate the teflon expulsion bladder. The ground test connections are used for component checkout and the manual valves are used for ground checkout and servicing.

The propellant tanks are cylindrical. They are of the positive expulsion type, with expulsion bladders which are compatible with the propellants to be contained. The oxidizer tank bladder is made of teflon and can require replacement as it has a limited expulsion or collapsing cycle service life (not time limited). The fuel tank bladder is made of butyl rubber and does not require replacement as it has an almost unlimited time and expulsion or flex cycle life. A flow path is provided through the propellant portion of the tanks for bleeding, purging, and drying. This port is designed such that each flow path to the atmosphere is sealed twice to increase the reliability of the tanks. The fuel and oxidizer tanks are 5.10 inches in outside diameter. The fluid volume capacity is 546.0 cubic inches for the oxidizer tank and 439.0 cubic inches for the fuel tank. The charged fluid volume capacity at 160°F for the design propellant weight is 535.0 cubic inches for the oxidizer tank and 400.0 cubic inches for the fuel tank.

5.3 DESCRIPTION AND OPERATION.- (Continued)

Component packages "C" and "D" contain essentially the same components: a normally closed cartridge-actuated valve, two manual valves, and a filter (Figure 10). The cartridge valves are used to isolate the propellants from the remainder of the system prior to system activation. The manual valves upstream of the cartridge valves are used for filling, draining, and purging of the propellants while the manual valves downstream from the cartridge valves are used for ground checkout of downstream component function. The filters are used to reduce the particle contamination of the propellants to a level acceptable to the TCA's.

All TCA's are installed submerged beneath the spacecraft moldline. Each one consists of two thrust chamber propellant valves, two calibration orifices, a fuel and oxidizer injection system, a combustion chamber, and an expansion nozzle (Figure 11). The propellant valves are quick acting, normally closed solenoid valves which open upon application of an appropriate electrical signal to permit flow of oxidizer or fuel to the injector to which they are fitted. The injector utilizes precise jets which impinge the fuel and oxidizer on one another for controlled mixing and good combustion efficiency. The calibration orifices are trim devices used in conjunction with the propellant valves and the injectors to adjust the flows to the design flow levels. The trim orifices are adjusted and fixed during TCA acceptance testing. The combustion chamber is the enclosed area between the injector face and the throat of the nozzle. The expansion nozzle is bell-shaped and contoured to terminate flush with the moldline of the spacecraft. The combustion chamber and the nozzle are lined with ablation material and insulation to control external wall temperature. Seals are provided between the nozzle and the spacecraft skin to prevent the backflow of exhaust gas into the spacecraft. A protective cover or plug is provided to protect the thrust chamber from entry of foreign matter when the TCA is not in use. The cover or plug is manually removed prior to launch and/or jettisoned in flight by the first start. NEW

Readouts of the temperature and pressure of the stored gas in the two systems are also provided on the temperature and pressure indicator on the astronauts' instrument panel (Figure 13). These readouts are also selected by means of the manual switching device. The temperature and pressure of the stored gas can be used to provide an indication of the pressurization capability available for the remainder of the mission. Regulated gas pressure and temperature are not transmitted to the indicator, but are telemetered to the ground stations for subsequent system analysis. REV

5.3 DESCRIPTION AND OPERATION.- (Continued)

Jettisoning of the remaining propellants in the two systems may be necessary after re-entry but prior to touchdown in order to assure crew safety during landing. Since rate damping is required up to deployment of the paraglider, jettisoning will occur after paraglider deployment. The propellants will be jettisoned by operating all yaw chambers simultaneously. Exhaust from these TCA's presents the least danger to the paraglider during either firing or dumping of propellant because the burned and unburned exhaust products will be carried away from the paraglider by the surrounding movement of air. If four yaw TCA's are fired per system, the propellants will be jettisoned at the rate of one-third pound per second, which for a full load of propellants (35 lbs.) would take 105 seconds. A full load of propellants may have to be jettisoned in the event that an abort becomes necessary.

5.4 DESIGN CRITERIA.- A propulsion system, capable of performing the RCS mission, was evolved from the design criteria listed below:

....Two completely redundant systems, sealed until retrograde, each of which can accomplish a nominal mission.

....Storable propellants having an advanced development background.

....Nitrogen used for pressurant because of low leakage characteristics. NEW

....Pure couples for roll control.

....No trans heatshield propellant or pressurant lines.

....A nozzle expansion ratio optimized for minimum over-all system weight.

....Pressurant storage pressure optimized for minimum over-all system weight.

....Compatible materials (and no dissimilar metals) for all component parts except the static seals in the high pressure manual valves and various non-exposed parts. In addition, no plating or surface treatment are allowed to make any surface compatible.

....Corrosion resistant steel lines, fittings and components, and titanium tanks and bottles.

....A butyl rubber bladder for the fuel tanks.

....A teflon bladder for the oxidizer tanks.

5.4 DESIGN CRITERIA.- (Continued)

....Packaging of several components to reduce weight, eliminate leaks, save space, and facilitate installation, servicing and testing.

....Components interchangeable between the RCS and the OAMS to reduce development and cost and increase reliability information; i.e., the pressure regulator and component packages "A" and "B".

....A system tailored to M.A.C./Rocketdyne philosophy for servicing and checkout. However, adequate connections and test points are incorporated so that any other selected procedure is not excluded. Design of the system is such that functional checks of all components can be made using gas, substitute test fluids, or propellants, with by-passes for packages "C" and "D".

....A diaphragm-relief valve series arrangement to provide assured zero leakage prior to activation of the pressure relief operation and then the limiting of the pressure venting to that required to protect the system.

....All dash numbered parts and packages are installed with threaded fittings.

....All non-threaded fitting connections are brazed or welded.

....No external leak paths through dynamic seals.

....Double and triple seal manual valves for service connections instead of the use of disconnects.

....Cartridge valve seals placed on the pressurant and the propellant tanks for reliable actuation, with a positive solid metal seal.

....Replaceable cartridge-actuated valves in component packages "C" and "D" so that the component does not have to be removed from the system to replace a fired unit.

....Main filters located downstream from the cartridge valves and the ground test connections for protection of downstream components.

....Supplemental filters provided at each solenoid valve, at each fill point, and in each cartridge valve for additional protection.

NEW

5.4 DESIGN CRITERIA.- (Continued)

....Non-replaceable filters for reduced weight and to prevent leakage.

....Check valves to provide protection against accidental propellant mixing in the regulated gas elements.

....Purge connections on the propellant tanks for servicing.

....Multi-expulsion bladders to allow several expulsions for system checkout.

....Individual, non-redundant in-line solenoid valves for TCA propellant valves to take advantage of accumulated development experience.

....Identical valves and injectors for all 25 pound TCA's in the RCS and the OAMS. Also, all RCS thrust chambers are identical.

....The duty life of the TCA's to include contingencies for all predicted uses.

NEW

5.5 DESIGN REQUIREMENTS

5.5.1 INPUTS AND FLUIDS

A. Pressurant.- The cold gas pressurant is nitrogen, conforming to Specification MIL-N-6011.

B. Propellants.- The bipropellant is:

Oxidizer - Nitrogen tetroxide (N_2O_4) conforming to Specification MIL-P-26539A.

Fuel - MMH - Monomethyl hydrazine ($N_2H_3CH_3$) conforming to Specification MIL-P-27403.

C. Electrical Inputs.- Electrical power for components other than instruments is taken from the common control bus at 22.0 to 30.0 volts D.C. Instrument power is taken from a regulated source at 5.0 volts D.C. $\pm$ 0.5%.

REV

5.5.2 PERFORMANCE.- The two systems exhibit the following vacuum performance characteristics:

A. System Performance

Design thrust level per TCA	25 pounds
Minimum steady state specific impulse	287 $\frac{\text{pound-sec.}}{\text{pound}}$
Minimum impulse bit required	.25 pound-sec.
Minimum specific impulse for minimum impulse bit	247 $\frac{\text{pound-sec.}}{\text{pound}}$
Pulse frequency range	0-6 $\frac{\text{pulses}}{\text{sec.}}$
Pulse width range	Minimum impulse bit width to continuous
Maximum TCA response time - time from application of electrical signal to 90% of maximum chamber pressure	25 milliseconds
Maximum TCA shutdown time - time from removal of electrical signal to 2% of maximum chamber pressure	7 milliseconds

B. Other System Parameters

Flow rate - at mixture ratio (O/F) of 2.0	
Oxidizer	.0555 lbs./sec.
Fuel	.0278 lbs/sec.
Mixture ratio - ratio of pounds of oxidizer to pounds of fuel injected into each TCA	2.0 ± 1%
Regulated pressure	280 psig
TCA chamber pressure	150 psia
Burst diaphragm rupture pressure range	420-500 psig
Relief valve operating pressure range	380-430 psig

5.5.3 WEIGHTS.- Target total weights for the two systems are as follows for both the two and fourteen day mission at 15°F:

A. System Dry Weight 109.2 lbs.

Components	(81.0)
Lines	(6.8)
Structure and Electrical	(21.4)

B. Propellant Weight (Loaded) 74.0

C. Propellant Weight (Usable) 70.0

D. Propellant Weight (Trapped and Residual) 4.0

E. Pressurant Weight 2.8

F. System Wet Weight 186.0

5.5.4 MATERIALS OF CONSTRUCTION.- Except for the ablation material in the TCA's, all internal wetted surfaces are fully compatible with the fluids contained therein. The pressurant and propellant storage tanks are fabricated of titanium alloy and corrosion resistant steel lines are used throughout the systems. Components are fabricated of corrosion resistant steel except in certain locations (e.g., springs, valve seats, bladders and solenoid coils) where functional requirements dictate the use of other more desirable materials of compatibility appropriate to their environment. REV

5.5.5 ASSEMBLY.- The components of the two systems are assembled into groups as shown in Figure 25.

5.5.6 INTERCHANGEABILITY.- System components which perform identical functions are directly and completely interchangeable with one another. Specifically, all thrust chamber assemblies used in these systems are interchangeable with one another.

5.5.7 COMPONENT LIFE.- All components are designed for a minimum of fifteen missions with an operating life comparable to at least one mission, with the following exceptions:

A. Cartridge-actuated valves have a one-shot life with a probability of satisfactory operation of at least 0.9999.

B. Expulsion tank bladders have a minimum life of six complete expulsions under service conditions.

5.5.7 COMPONENT LIFE.- (Continued)

C. Thrust Chamber Assembly life consists of operation, either continuous or in pulsing mode, wherein pulse frequency and duration is randomly distributed between 0 and 6 pulses per second and 0.010 and 2.0 seconds per pulse, respectively. Individual life ratings are:

All Thrust Chamber Assemblies................162 seconds

5.5.8 GROUND CHECKOUT.- Ground checkout consists of leakage measurements and functional checks of all components using nitrogen gas at suitable pressures. Component gas flow rate calibrations are performed and comparisons made with acceptability standards. The manual valves and the ground test connections are used for component checkout. A complete functional checkout of every component can be performed if necessary, including the firing of the TCA's with propellant.

5.6 ENVIRONMENTAL CONDITIONS.- The two systems function in accordance with this specification when subjected to any natural combination of the environments shown in Tables II and IV.

5.7 STRUCTURAL REQUIREMENTS.- All components of the two systems are designed for the pressures defined in Sections 5.7.1 and 5.7.2. The components also withstand, without permanent deformation, the limit acceleration and shock loads from Tables II and IV, the maximum rated thrust of the TCA units, and any loads which may result from the operation of the systems. Ultimate design loads of which structural failure shall not occur are 1.36 times limit loads. An additional 1.5 factor is used on any castings in the components. When critical, the ultimate strength provides for a minimum of 1.36 times limit loads combined with the design pressures of Sections 5.7.1 and 5.7.2. All components are designed for the critical flight conditions with the proper pressurant and propellant quantity, with an additional condition considered using the design landing criteria with full pressurized components. Limit temperatures are shown in Tables II and IV, and operating temperatures will be determined by tests. Ultimate heating effects are considered by increasing limit temperatures to 200°F under certain specified conditions. Ultimate design conditions are either ultimate loads or proper combinations thereof combined with limit temperatures or ultimate heating effects combined with limit loads.

5.7.1 PRESSURES AND TEMPERATURES

A. <u>Normal Operating Pressures</u>.- The normal operating pressures for components located upstream of the pressure regulator (including the regulator inlet) are 3000 psig and regulated pressure (280 psig) for components located downstream from the pressure regulator (and including the regulator outlet).

R E V

5.7.1 PRESSURES AND TEMPERATURES.- (Continued)

B. Normal Operating Temperature.- The normal operating temperature is 70°F.

C. Design Pressures.- The design pressure for components located upstream of the pressure regulator is 3000 psig. The design pressure for components located downstream from the regulator is 300 psig.

D. Design Temperature.- The design temperature spans the range of +15°F to +160°F.

E. Proof Pressures.- Component proof pressure at 70°F is 150% of the design pressure, except that for the pressurant storage and the propellant tanks it is 167% of the design pressure.

F. Burst Pressures.- Component burst pressure at 70°F is 250% of the design pressure, except that for the pressurant storage and the propellant tanks it is 222% of the design pressure.

REV

5.7.2 TABULATION OF OPERATING, PROOF AND BURST PRESSURES FOR COMPONENTS

Component Class	Normal Operating Pressure (psig)	Design Pressure (psig)	Proof Pressure % of Design Pressure	Proof Pressure (psig)	Minimum Burst Pressure % of Design Pressure	Minimum Burst Pressure (psig)
High Pressure Components	3000	3000	150	4500	250	7500
a) Pneumatic Spheres	3000	3000	167	5010	222	6660
Pressure Regulator						
a) Inlet	3000	3000	150	4500	250	7500
b) Outlet	280	300	150	450	250	750
Regulated Pressure Components	280	300	150	450	250	750
a) Propellant Tanks	280	300	167	500	222	666

NEW

TABLE IV

DESIGN ENVIRONMENTAL CONDITIONS FOR RE-ENTRY CONTROL SYSTEM EQUIPMENT LO

Design Environment \ Equipment Life Phase	Transportation and Prelaunch (Operating and Nonoperating)	Launch (Operating or Nonoperating)	
Ambient Temperature (2)	+20°F to 160°F (Serviced) and -60°F to 160°F (Unserviced).	+15°F to 160°F	+1
Ambient Pressure	15.5 to 1.4 psia	15.5 to 10^{-12} psia	10
Temperature-Pressure	N.A. (1)	160°F at 15.5 to 10^{-12} psia	16
Relative Humidity	15% to 100%	15% to 100%	N.
Rain	MIL-E-5272C, Procedure II	N.A.	N.
Salt Sea Atmosphere	MIL-E-5272C, Procedure I	N.A.	N.
Sand and Dust	MIL-E-5272C, Procedure I	N.A.	N.
Fungus (3)	MIL-E-5272C, Procedure I	N.A.	N.
Shock (4) (5) (6)	N.A. (Prelaunch) and Protected per M.A.C. Report 8757 (Transportation)	N.A.	N.
Acceleration (4) (5)	N.A. (Prelaunch) and Protected per M.A.C. Report 8757 (Transportation)	Longitudinal Spacecraft Axis: 1g to 7.25g's, linearly with time over 326 sec. Lateral Spacecraft Axes: 4.0g's in any direction for 1 sec. (6)	O
Vibration			
Category A (Figure 15)(9)	N.A. (Prelaunch) and Protected per M.A.C. Report 8757 (Transportation)	Curve I	Cu
Category B (Figure 16)(10)	N.A. (Prelaunch) and Protected per M.A.C. Report 8757 (Transportation)	Curve I	Cu
Acoustic Noise	N.A. (Prelaunch) and Protected per M.A.C. Report 8757 (Transportation)	145 db Over-all, See Figure 27	N.
Radio Interference	MIL-I-26600	MIL-I-26600	M
Explosive Atmosphere	N.A.	N.A.	N.

NOTES:

1. N.A. = Not applicable.
2. These are the design extreme temperatures for the propellant tank and distribution system. The combustion chamber is designed for a maximum external temperature of 500°F.
3. Applicable to untested and untreated materials only.
4. Lateral Spacecraft Axes refers to both the pitch and yaw axes as defined for spacecraft control.
5. All shock and acceleration loads in this table are limit loads. Satisfactory performance is required during and/or after limit load application, whichever is appropriate. No equipment shall tear loose from its mount and internal parts shall be contained under application of ultimate loads. Ultimate load is 1.36 times limit load.
6. Longitudinal and Lateral do not
7. Area I is in the Re-Entry Modul 160.00 and 192.00 (Upper Cabin Section). Area II is in the Re Z Stations 103.44 and 160.00 (
8. Longitudinal and Lateral act si
9. Equipment items which are moun structure directly or through and/or are of sufficiently sma mechanical impedance of the sp seen by the equipment installa be considered effectively infi

:V

LOCATED IN THE RE-ENTRY MODULE EXTERNAL TO THE PRESSURIZED CABIN

Orbit (Operating or Nonoperating)	Re-Entry and Landing (Operating)	Post-Landing (Nonoperating)
+15°F to 160°F	+15°F to 160°F	+20°F to 160°F
10^{-12} psia	10^{-12} to 15.5 psia	15.5 psia
160°F at 10^{-12} psia	160°F at 10^{-12} to 15.5 psia over 10 minutes	N.A.
N.A.	15% to 100%	15% to 100%
N.A.	N.A.	MIL-E-5272C, Procedure II
N.A.	N.A.	MIL-E-5272C, Procedure I
N.A.	N.A.	MIL-E-5272C, Procedure I
N.A.	N.A.	MIL-E-5272C, Procedure I
N.A.	Area I - 30g's along Longitudinal Spacecraft Axis and 30g's along either Lateral Spacecraft Axis, 11 ms duration. (7) Area II - See Figure 19 (7).	15g's in any direction, 11 ms duration.
0g	Longitudinal Spacecraft Axis: 15g's, 30 sec. duration. Lateral Spacecraft Axes: 4.5g's, 30 sec. duration. (8)	1g
Curve II	Curve III	N.A.
Curve II	Curve III	N.A.
N.A.	Same as for Launch	N.A.
MIL-I-26600	MIL-I-26600	MIL-I-26600
N.A.	N.A.	N.A.

:ot act simultaneously.
:ule between Z Stations
n Section and RCS
Re-Entry Module between
(Main Cabin Section).
simultaneously.
nted to spacecraft primary
intervening structure
all mass that the
pacecraft structure as
ation attach points can
inite.

10. Equipment items or complete system installation of sufficiently large size and mass that the mechanical impedance of the attach points cannot be taken as infinite, and the feedback mechanism has been given consideration.

REV

DATE 18 July 1962

REVISED

REVISED

MCDONNELL

ST. LOUIS, MISSOURI

REPORT 8642

MODEL GEMINI

GEMINI SPACECRAFT ACOUSTIC ENVIRONMENT SPECTRUM

(IN THE RE-ENTRY MODULE EXTERNAL TO THE PRESSURIZED CABIN)

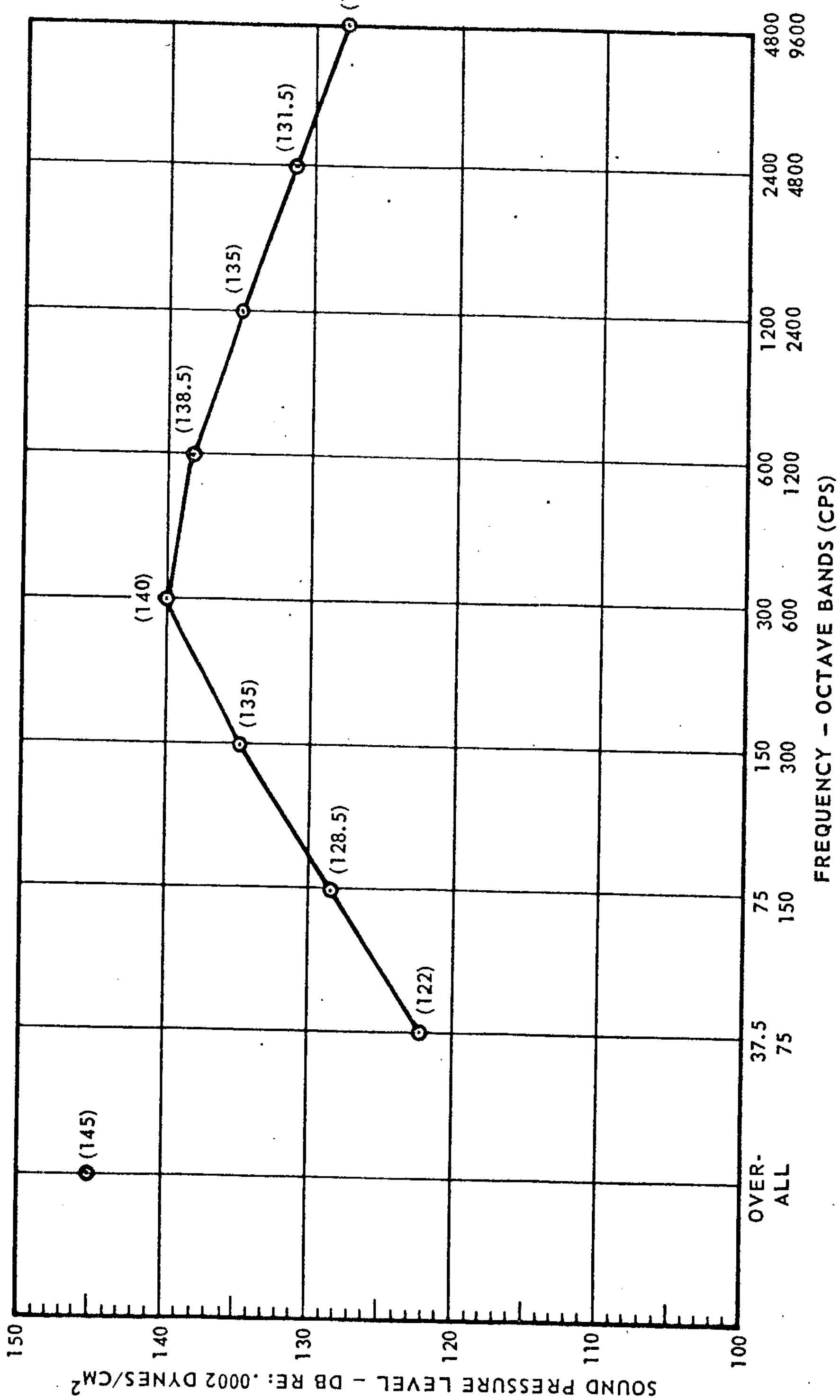


Figure 27

6. QUALITY ASSURANCE

6.1 GENERAL.- System components and materials are subjected to both acceptance and design approval tests. Acceptance tests include, but are not limited to those tests performed to insure that the materials, workmanship, and performance of components are not substandard, and that the components have been manufactured to approved drawings and specifications. Design approval tests are defined as those tests conducted on pre-production and/or production equipment to determine that the design of the equipment complies with all requirements therefor. In addition, production-line surveillance is maintained during fabrication, assembly, and installation of all components and subassemblies to assure that all methods, procedures,and ambient conditions are maintained in accordance with existing specifications and established spacecraft standards. Quality assurance provisions are in accordance with M.A.C. Report 8580-7, "Quality Assurance Provisions (Plan) for Project Gemini Space System."

7. RELIABILITY

7.1 GENERAL.- An active reliability program is established and conducted throughout the design,development, fabrication, and installation of the Propulsion Systems. Adequate testing, both in-plant and/or vendor/subcontractor-accomplished, is performed to insure a reliability factor which does not deteriorate the over-all probability of a successful mission. Mission safety is emphasized in the design approach, back-up and redundant systems are utilized where necessary, and every effort is made to minimize system complexity. Reliability provisions are in accordance with M.A.C. Report 8580-3, "Project Gemini Reliability Plan." R E V

8. DATA REQUIREMENTS

8.1 GENERAL.- Applicable design information and performance reports are submitted in accordance with the requirements specified in M.A.C. Report 8580-8, "Model 133P Gemini Program Documentation Plan."

APPENDIX I
EQUIPMENT LIST

APPENDIX I

EQUIPMENT LIST

ORBIT ATTITUDE AND MANEUVER SYSTEM

Quantity		Nomenclature	M.A.C. Part No.
Two Day Mission	Fourteen Day Mission		
1	1	Component Package "A"	52-52700-5
1	1	Pressure Regulator	52-52700-7
1	1	Component Package "B"	52-52700-9
1	1	Indicator-Temperature and Pressure	52-52700-21
8	8	Thrust Chamber Assembly (25 lb.)	52-52701-3
6	2	Thrust Chamber Assembly (100 lb.)	52-52701-5
2	0	Thrust Chamber Assembly (85 lb.)	52-52701-7
2	1	Oxidizer Tank	52-52701-9
2	1	Fuel Tank	52-52701-11
2	1	Pressurant Storage Tank	52-52701-13
1	1	Propellant Quantity Gauging System	52-52701-17
1	1	Component Package "C"	52-52701-21
1	1	Component Package "D"	52-52701-23
2	2	Cartridge for -21 and -23	52-52701-25
2	2	Propellant Shutoff Valve	52-52701-31
1	1	Cartridge for -39 for N.O. Valve	52-52701-35
1	1	Component Package "E"	52-52701-39
1	1	Cartridge for -39 for N.C. Valve	52-52701-41
2	0	Propellant Line Guillotines	52-72708-1

NEW

APPENDIX I (Continued)

EQUIPMENT LIST

RE-ENTRY CONTROL SYSTEM

Quantity Two Day Mission	Quantity Fourteen Day Mission	Nomenclature	M.A.C. Part No.
8	8	Thrust Chamber Assembly (25 lb.)	52-52700-3
1	1	Component Package "A"	52-52700-5
1	1	Pressure Regulator	52-52700-7
1	1	Component Package "B"	52-52700-9
1	1	Component Package "C"	52-52700-11
1	1	Component Package "D"	52-52700-13
1	1	Oxidizer Tank	52-52700-15
1	1	Fuel Tank	52-52700-17
1	1	Pressurant Storage Tank	52-52700-19
1	1	Indicator-Temperature and Pressure	52-52700-21
1	1	Cartridge for -5	52-52700-23
1	1	Cartridge for -11 and -13	52-52700-25

RETROGRADE ROCKET SYSTEM

Quantity Two Day Mission	Quantity Fourteen Day Mission	Nomenclature	M.A.C. Part No.
4	4	Retrograde Rocket Motors	52-50702

NEW

APPENDIX II
LIST OF CHANGES

APPENDIX II

LIST OF CHANGES

Following is an itemized list of changes incorporated in M.A.C. Report 8642 as a result of successive revisions. In instances where conflict or confusion may result, the authority for these changes is parenthetically specified; where the reason for change is self-explanatory (e.g., re-arrangement of format, addition of reference material, rewording for clarity or additional information, etc.), no authorization is listed.

Section 1

Changes Incorporated in 6 June 1962 Revision

Reference: A. Project Gemini Abstract of Technical Negotiation Meeting on Propulsion Systems, dated 1 May 1962

NEW

Paragraph	Changes
Title Page	Added revision date, changed the title of the report, and deleted the downgrade note.
Approval Sheet	Revised to incorporate additional approvals.
Table of Contents	Revised to reflect changes made in the report revision.
List of Figures and Tables	Revised the numbers and titles of the original figures and tables, deleted original Table IV, and added Figures 6 through 27.
List of Effective Pages	Added new pages incorporated into the revised report.
Index of Revisions	Added (as required).
1.1	Changed the titles of the report and the individual propulsion systems.
2.1	Changed "Subsystems" to "Systems".

APPENDIX II

LIST OF CHANGES (Continued)

Paragraph	Changes
2.2.1	Deleted M.A.C. Report 8433, added M.A.C. Drawing 52-50702 and M.A.C. Reports 8611 and 8637, and changed titles of M.A.C. Drawings 52-52700 and 52-52701.
3.	Revised the entire section to incorporate additional information and figures as well as more current information (per NASA request); added a paragraph containing the design criteria for the OAMS (per NASA request); revised the applicable paragraphs, tables, and figures in this section (per NASA comments in Items 1 through 10 and 17 of Reference A); and incorporated component operating pressures more current than those shown in Item 11 of Reference A.
4.	Revised the entire section to incorporate information, tables, and figures on the retrograde rocket system that will be used in all spacecraft providing that the delivery schedule is compatible with vehicle launch, including the comments noted in Items 12 through 16 of Reference A.
5.	Revised the entire section to incorporate additional information and figures as well as more current information (per NASA request); added a paragraph containing the design criteria for the RCS (per NASA request); revised the applicable paragraphs, tables, and figures in this section (per NASA comments in Items 4 through 8 and 10 of Reference A); and incorporated component operating pressures more current than those shown in Item 11 of Reference A.
7.1	Changed "Subsystems" to "Systems".
Appendix I	Added a list of equipment section.

NEW

APPENDIX II

LIST OF CHANGES (Continued)

Paragraph	Changes
Appendix II	Added a list of changes section.
Addendum A	Revised this entire section (which was previously Section 4) to incorporate additional information and figures as well as more current information on the alternate retrograde rocket system that may be required for the earlier spacecraft in the event that the system described in Section 4 is not available; and incorporated the comments noted in Items 12 through 16 of Reference A.

NEW

ADDENDUM A
ALTERNATE SYSTEM

ADDENDUM A

ALTERNATE RETROGRADE ROCKET SYSTEM

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TABLE OF CONTENTS

NEW

LIST OF FIGURES AND TABLES

NEW

A-1. GENERAL.- This addendum describes the alternate retrograde rocket system that will be used in the earlier spacecraft in the event that the rocket motors described in Section 4 are not available for installation. These rocket motors are also mounted in the retrograde section of the adapter, symmetrically located about the longitudinal axis of the spacecraft as shown in Figure A-1.

A-2. OPERATION.- Retrograde rocket operation permission is established by manually arming the retrograde squib firing circuits, after which the firing sequence is controlled either automatically through the time reference system or manually by the crew. Thirty seconds prior to actual retrograde firing (TR-30), the electronic timer illuminates the RETRO ARM indicator/push button on the astronauts' instrument panel. The automatic firing circuit is then manually armed. At TR-0 the electronic timer initiates the retro-fire sequence. The rockets are then fired at five-second intervals. Rocket number 1 is the first to be fired, followed thereafter by number 2 and 3 rockets, respectively (see Figure A-1). Number 4 rocket is not used during the normal retrograde sequence and is reserved as a back-up rocket in the event a malfunction occurs in the firing of one of the other three rockets. The crew will ascertain by the stepped acceleration inputs that all three rockets have fired successfully. The rockets are fired in salvo for a mission abort. REV

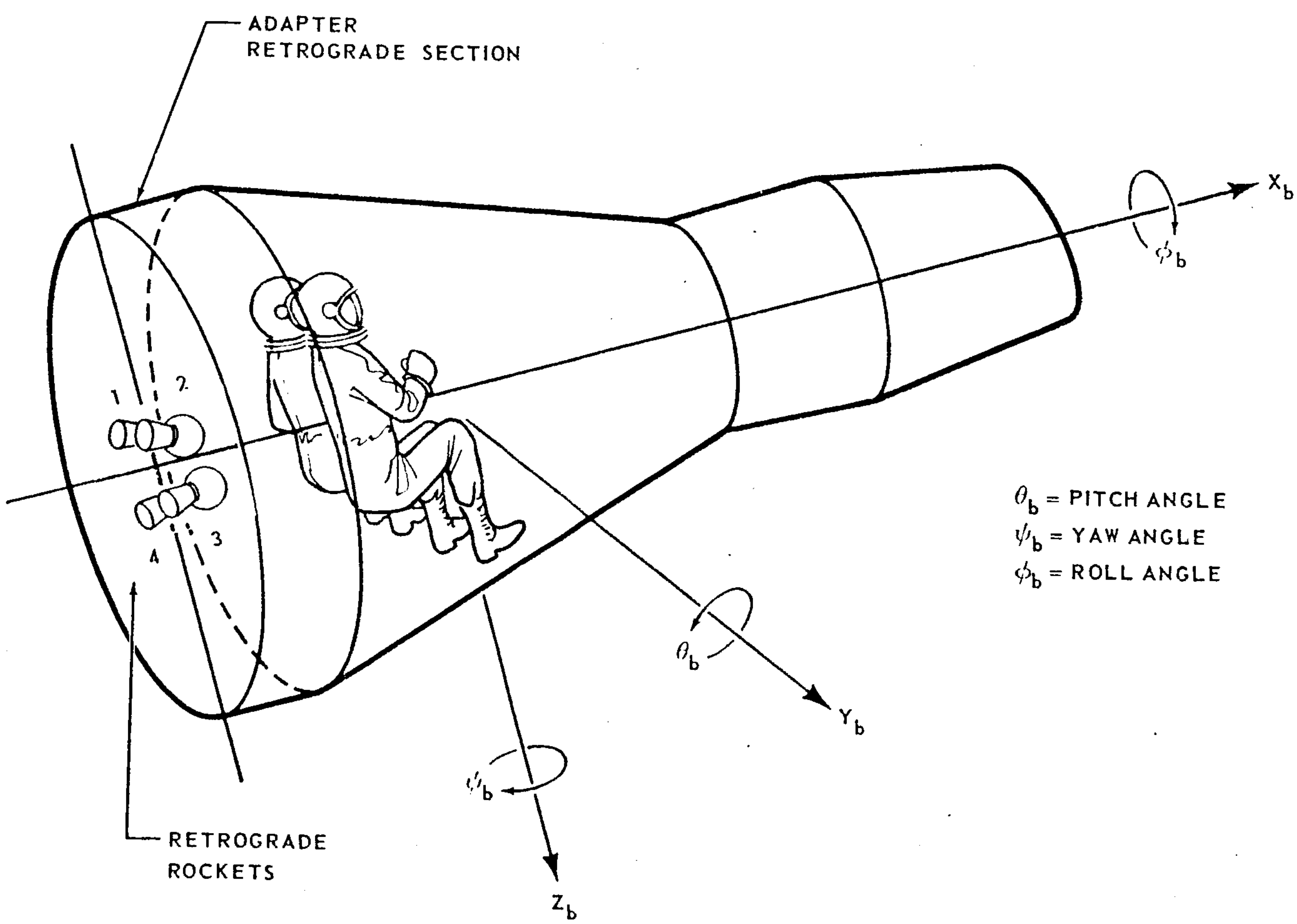
A-3. DESIGN REQUIREMENTS

A-3.1 RETROGRADE ROCKET.- The four retrograde rocket motors employed in this system are identical in design and performance, containing well-characterized polyurethane/ammonium perchlorate propellant and dual pyrogen igniters in each unit, as shown in Figure A-2. A modified version of the Thiokol TE-345 rocket, the retrograde rocket is a 13.5 inch diameter spherical motor with a 17-7PH stainless steel case, a partially-submerged nozzle with a 40:1 expansion ratio, and internally-mounted pyrogen igniters with removable initiators. It is approximately 20.6 inches in over-all length.

Each rocket delivers a total impulse of 18,400 pound-seconds at an average thrust of 860 pounds over a burning time of 20.6 seconds. These performance ratings are based on a propellant bulk temperature of +60°F and vacuum operation. Rocket performance, weight, and other pertinent design parameters are shown in Figure A-3.

The rockets are beam-mounted in the retrograde section of the adapter as shown in Figure A-4 and are individually aligned in the adapter prior to adapter/re-entry module mating, so as to minimize the eccentricity between the thrust vector and the retrograde weight center-of-gravity.

ALTERNATE RETROGRADE ROCKET ARRANGEMENT



NOTE:
POSITIVE SENSE OF AXES AND ANGLES INDICATED BY ARROWS

Figure A-1

NEW

ALTERNATE RETROGRADE ROCKET ASSEMBLY

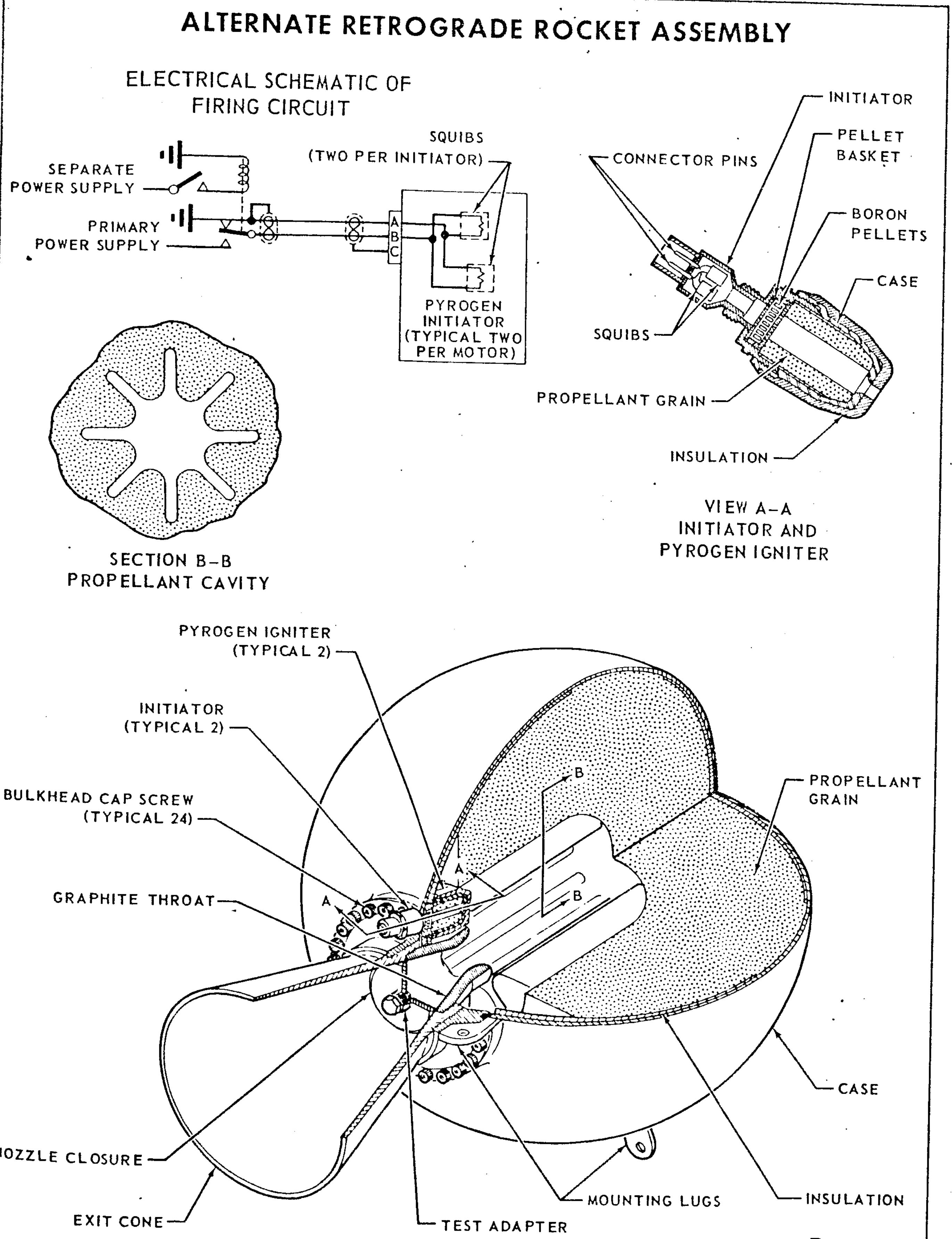


Figure A-2

ALTERNATE RETROGRADE ROCKET PERFORMANCE, WEIGHT, AND DESIGN PARAMETERS

PERFORMANCE AT 60°F AND VACUUM OPERATION

AVERAGE PRESSURE OVER BURNING TIME (PSIA)	560
AVERAGE THRUST OVER BURNING TIME (LB.)	860
TOTAL IMPULSE OVER ACTION TIME (LB.-SEC.)	18,400
IGNITION TIME; TIME TO 75% P_{MAX} (MILLISECONDS)	100 (MAX.)
BURNING TIME (SECONDS)	20.6
ACTION TIME (SECONDS)	21.6
SPECIFIC IMPULSE (LB.-SEC./LB.)	275

WEIGHTS (POUNDS)

PROPELLANT	65.60
LINER	0.45
INERT PARTS	14.11
IGNITER (2)	0.86
TOTAL	81.02 (NOM.)

NOZZLE DESIGN

EXPANSION RATIO	40:1
EXIT AREA (IN.^{2})	32.0
THROAT AREA (IN.^{2}) – INITIAL	0.803
– FINAL	0.935

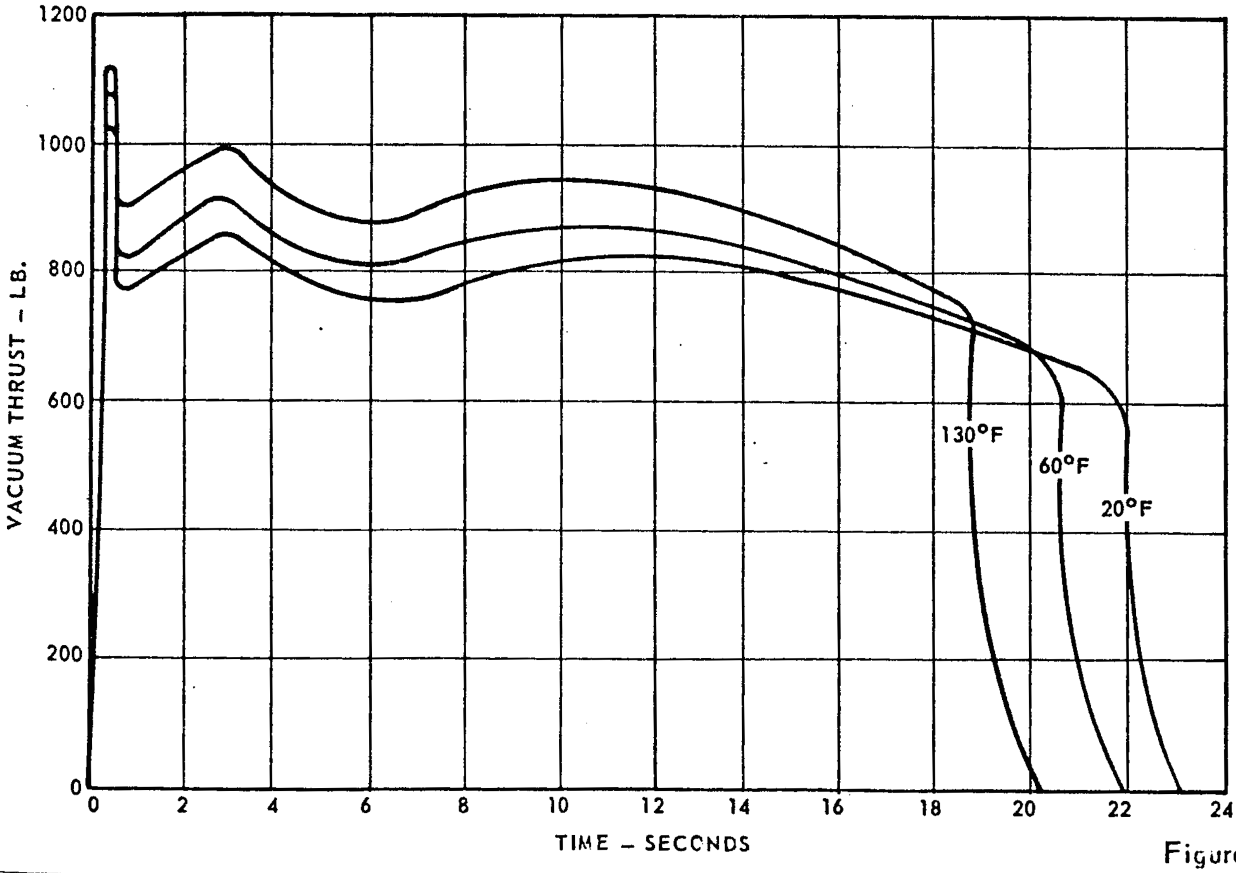


Figure A–3

R E V

ALTERNATE RETROGRADE ROCKET SYSTEM INSTALLATION

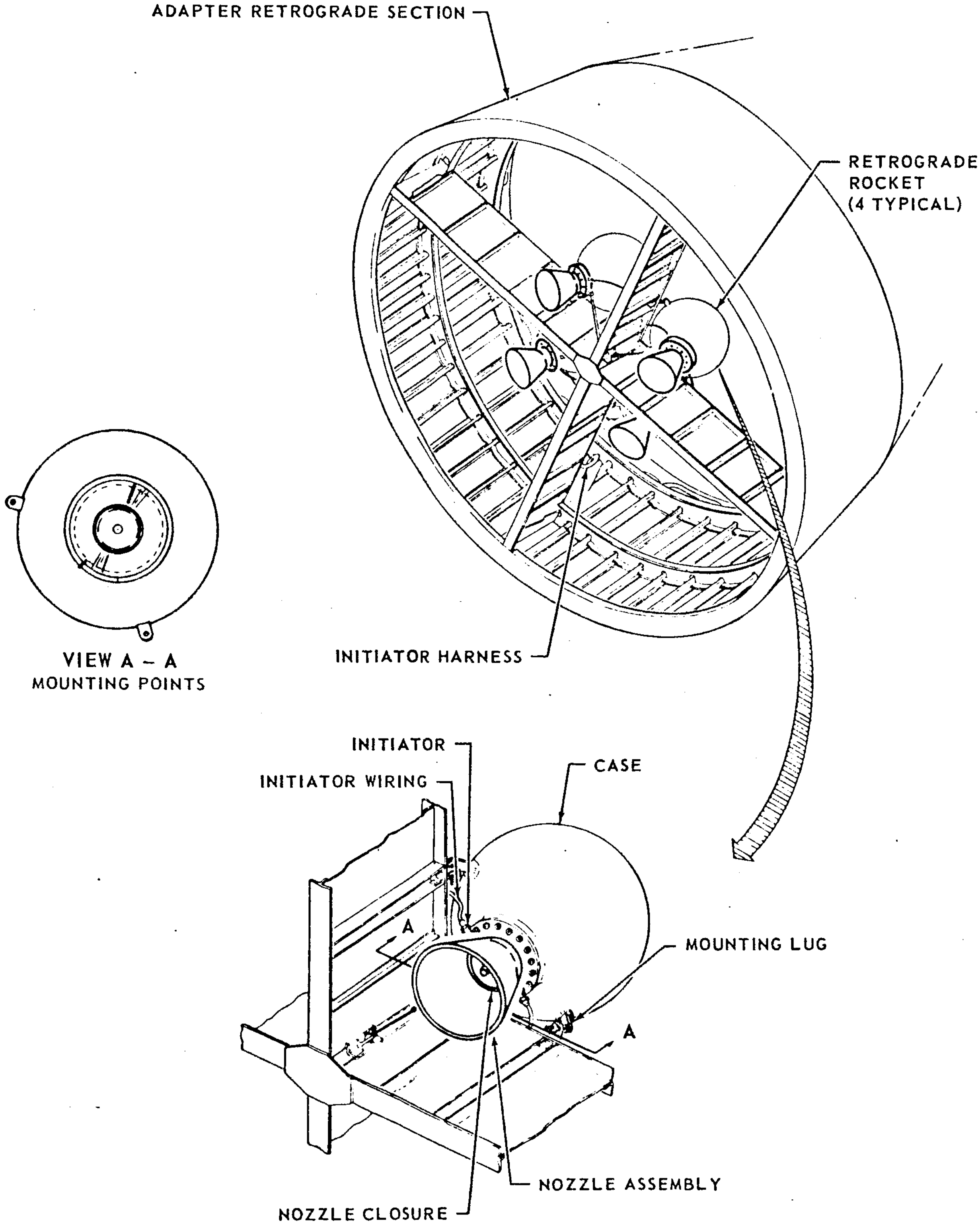


Figure A-4

NEW

A-3.1.1 NOZZLE ASSEMBLY AND CASE.- The rocket motor has a 17-7PH stainless steel spherical (13.5 inch diameter) case, which is formed from two hemispherical halves welded together. Each half is hydro formed to a minimum wall thickness of 0.030 inches. The wall is of constant thickness except for a gradual thickening transition section at the nozzle attachment boss.

The attachment fittings are furnace-brazed to the case during the heat treat operation. The case assembly is than annealed to 1050°F and air quenched.

The nozzle assembly is mounted to the motor case by twenty-four 1/4 inch cap screws. The nozzle design consists of a ATJ graphite throat and a vitreous silica-phenolic exit cone providing a nozzle expansion ratio of 40:1. The nozzle throat insert is recessed in the motor chamber to decrease over-all motor length. The maximum deviation in thrust alignment resulting from changes in nozzle symmetry during motor firing is 10 minutes of one degree.

To protect the case walls from the high temperature combustion products, a laminated vitreous silica-phenolic insulation material is bag molded to the case walls. The motor is then lined with a urethane type material compatible with the propellant system to achieve a reliable propellant-to-case bond.

A-3.1.2 SOLID PROPELLANT.- The propellant used in the rocket motor is comprised of a polyurethane fuel and ammonium perchlorate oxidizer which is cast and cured in the motor chamber. The eight-pointed star design used for the propellant port results in a moderate "saddle" in the thrust-time history, as can be seen in Figure A-3.

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The propellant can be stored for two years or more within the temperature range of +10°F to +110°F without deteriorating to the extent where the rocket motor cannot meet the performance requirements of this specification. It is also extremely reliable over the operating temperature regime of +20°F to +130°F. It's autoignition temperature is in excess of 275°F for one hour and 225°F for eight hours.

A-3.1.3 IGNITION SYSTEM.- Two independent and redundant pyrogen type igniters are used in each motor. Mounted internal to the motor, each pyrogen igniter is essentially a small, internal burning, solid-propellant rocket motor with its own initiator and igniter pellets. The motor is prepared for firing by inserting the squib-actuated initiators into each pyrogen igniter. The initiator ignites the pyrogen propellant which discharges its exhaust gases into the motor cavity, providing the pressure and thermal energy to ignite the surface of the motor propellant grain in a smooth, reproducible manner. The pyrogen provides a sustained discharge for approximately 200 milliseconds to assure a high level of confidence in reliable vacuum ignition.

A-3.1.3 IGNITION SYSTEM.- (Continued)

The pyrogen case and cap are machined from 304 stainless steel and are insulated with a vitreous silica-phenolic material to prevent motor burn-through in the igniter area after ignition is accomplished. The pyrogen employs a booster charge consisting of boron/potassium nitrate pellets and a sustainer charge of polysulfide/ammonium perchlorate propellant.

Each of the pyrogen initiators contains two electrically-actuated squibs and is capable of withstanding a one amp, one watt current/power input for five minutes without firing and is capable of firing with the current limited to four amperes. A firing lead cable is connected to a Bendix PT type receptacle incorporated in each initiator. The design is such that if the electrical power to one is interrupted, the other is adequate to ignite the motor with the same reliability as exists when both systems are operative.

A-4. ENVIRONMENTAL AND LOAD REQUIREMENTS

A-4.1 ENVIRONMENTAL CONDITIONS.- The rocket motor and packaged igniter (handling and storage) or installed igniter (prelaunch and launch) do not suffer any detrimental effects during and after exposure to extreme temperature, rain, salt spray, sand and dust, and humidity as defined by Table A-I. Only nonnutrient materials are used in the construction of the rocket motor and the components thereof.

Materials used in the construction of the unit that are subject to deterioration when exposed to climatic and environmental conditions likely to occur under the conditions specified in Table A-I are protected against deterioration in a manner that will in no way prevent compliance with required motor performance. Protective coatings that will crack, chip, or scale with age or extremes of climate and environmental conditions are not used.

The unit is designed for storage and operation at relative humidities up to 100 per cent, including condensation due to temperature change.

A-4.1.1 OPERATING REGIMES

A-4.1.1.1 ALTITUDES AND TEMPERATURES.- The rocket motor ignites and operates satisfactorily throughout the ambient pressure range of 15.5 to 0 psia and as follows:

A. Static Exposure - The rocket motor performs satisfactorily after static exposure to a minimum ambient temperature environment of +130°F for a period long enough to condition the entire mass of the engine to +130°F and after exposure to a maximum temperature environment of +20°F for a period long enough to condition the entire mass of the motor to +20°F.

TABLE A-I
DESIGN ENVIRONMENTAL CONDITIONS FOR
ALTERNATE RETROGRADE ROCKET SYSTEM EQUIPMENT LOCATED IN THE ADAPTER

Design Environment \ Equipment Life Phase	Prelaunch	Launch	Orbit
Ambient Temperature	+20°F to 130°F (2)	+20°F to 130°F (2) (3)	+20°F to 130°F (2) (3)
Ambient Pressure	15.5 to 1.4 psia	15.5 to 0 psia (2) 1.4 to 0 psia (3)	0 psia (2) (3)
Relative Humidity	15% to 100%	15% to 100%	N.A. (1)
Salt Sea Atmosphere	Protected for 50 hrs. in Salt Sea Atmosphere	N.A.	N.A.
Sand and Dust	Protected for 50 hrs.	N.A.	See Note (4)
Fungus	Protected (5)	N.A.	N.A.
Shock	15g's, 11 milliseconds in any direction (6)(7)(8)	N.A.	N.A.
Acceleration	±6g's steady state all three axes (6)(7)(8)	1g longitudinal increasing linearly to 7.25g's in 326 seconds (6)(7)	0.7g for 30.6 sec. at an angle of 16° with the longitudinal centerline of the motor chamber (3)(6)(7)
Vibration	Protected	Curve I of Figure A-5	Curve II of Figure A-5
Acoustic Noise	Protected	155 db Overall, see Figure A-6	N.A.
Radio Interference	Protected	Protected	Protected
Radiation	N.A.	N.A.	See Note (9)

1. N.A. - Not Applicable.
2. Nonoperating (prelaunch soak temperature).
3. Operating.
4. Seller to comment on the effects of meteoroid dust.
5. Only non-nutrient materials are used in the construction of the rocket motor and the components thereof.
6. The component shall be operable over the limit loads shown; however, for strength purposes, it shall be designed for 1.36 times the limit loads.
7. See Figure A-7 for direction of positive longitudinal acceleration (Q direction).
8. These loads shall be applied to packaged motors.
9. To be commented on by Seller.

GEMINI SPACECRAFT VIBRATION SPECTRA

EQUIPMENT CATEGORY A

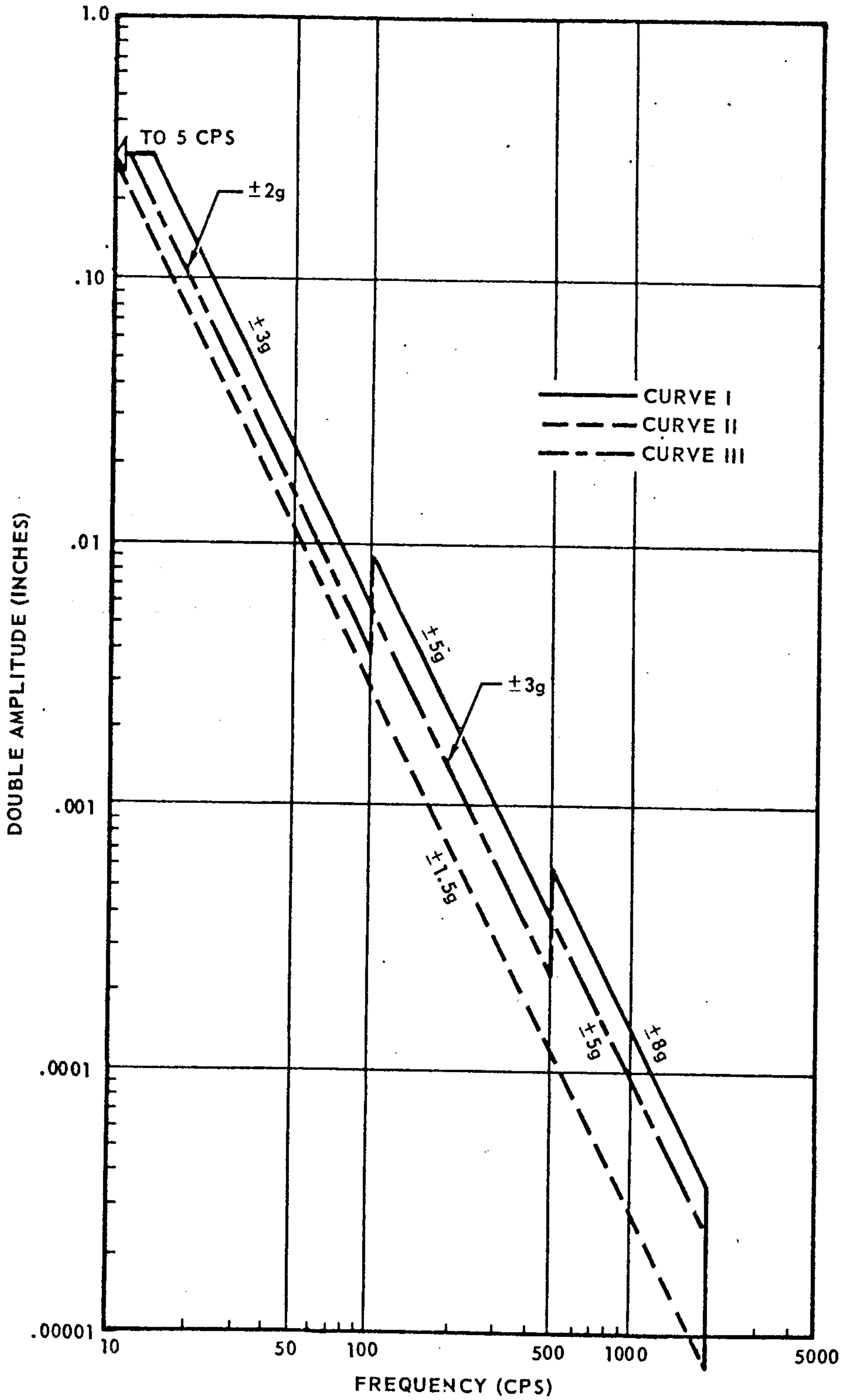

Figure A-5

NEW

GEMINI SPACECRAFT ACOUSTIC ENVIRONMENT SPECTRUM

(IN THE ADAPTER)

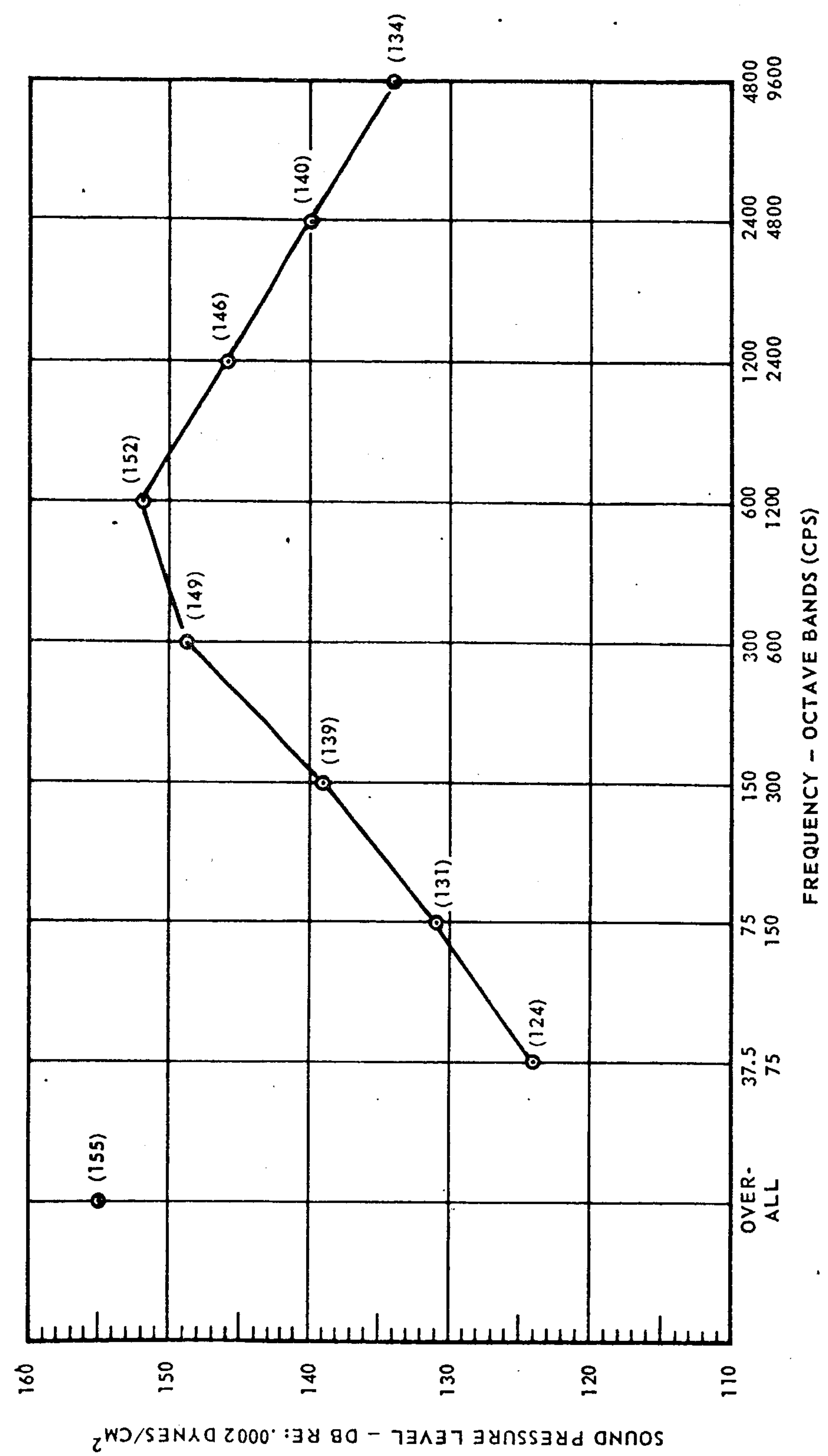

Figure A-6

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A-4.1.1.1 ALTITUDES AND TEMPERATURES.- (Continued)

B. Flight Operation - The rocket motor ignites and performs satisfactorily, exhausting to vacuum conditions.

C. Temperature Gradients - The rocket motor performs safely and consistently with the thermal condition of the grain after exposure to a minimum ambient temperature of +130°F for a period long enough to condition the entire mass of the motor to +130°F and fired after exposure to a maximum ambient temperature of +20°F until the maximum temperature gradient exists within the propellant grain. It also performs satisfactorily when conditioned to a maximum temperature of +20°F and then fired after exposure to a minimum ambient temperature of +130°F until the maximum temperature gradient exists in the propellant grain.

A-4.1.2 STORAGE TEMPERATURE RANGE AND ATTITUDE.- The rocket motor and packaged igniter under field storage conditions do not suffer any detrimental effects when exposed to the prelaunch temperature range as presented in Table A-I and when stored in any attitude. The total accumulated storage time above +130°F will not exceed two weeks.

A-4.1.3 LIMITING EXPOSURE TIME.- The rocket motor operates within specification limits after exposure to a temperature varying from +20°F to +130°F and a vacuum environment for a period not less than fourteen days.

A-4.1.4 VIBRATION.- The rocket motor, with installed igniters, is capable of withstanding without deleterious effects the vibrations as presented in Table A-I.

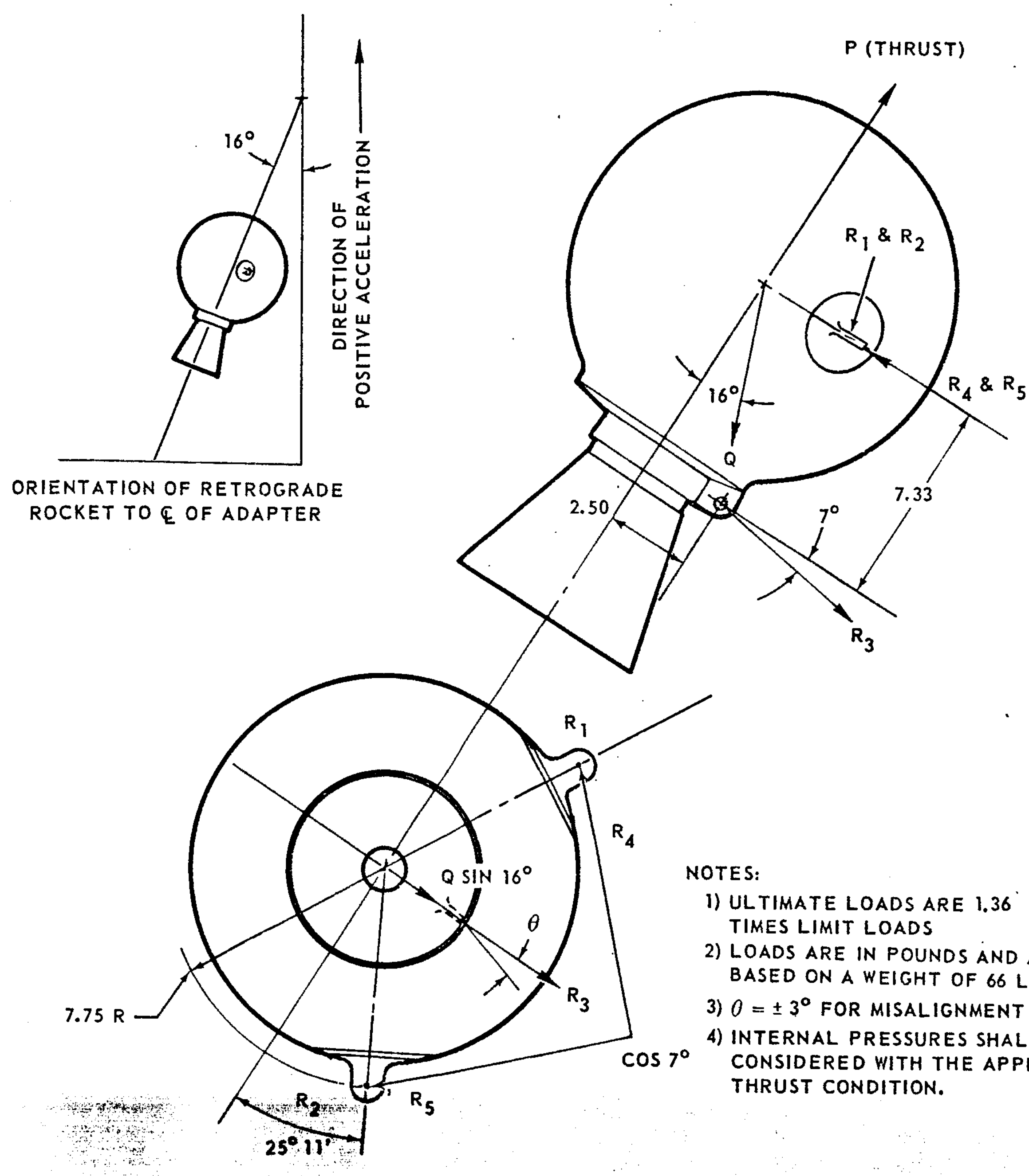
A-4.1.5 DROP.- The packaged rocket motor with installed igniters and packaged igniter initiators will perform satisfactorily after being subjected to a four foot drop onto solid reinforced concrete.

A-4.1.6 ACOUSTIC NOISE.- The rocket motor and installed igniter are capable of withstanding acoustic noise as specified in Table A-I without deleterious effects.

A-5. STRUCTURAL REQUIREMENTS.- The rocket motor and its supports are capable of withstanding without permanent deformation the forces resulting from the loads specified in Figure A-7 and Table A-I. For design purposes, the ultimate strength provides for a minimum of 1.36 times the forces resulting from the loads specified in Figure A-7 and Table A-I. The proof and burst pressure limits of the thrust chamber exceed the maximum pressure based on either the maximum ignition pressure or the maximum chamber pressure at +130°F, whichever is larger, by factors of 1.1 and 1.4, respectively.

REV

LIMIT LOADS FOR ALTERNATE RETROGRADE ROCKET



NOTES:

1) ULTIMATE LOADS ARE 1.36 TIMES LIMIT LOADS
2) LOADS ARE IN POUNDS AND ARE BASED ON A WEIGHT OF 66 LBS.(MAX.)
3) $\theta = \pm 3^\circ$ FOR MISALIGNMENT
4) INTERNAL PRESSURES SHALL BE CONSIDERED WITH THE APPLICABLE THRUST CONDITION.

CONDITION	P	Q	R_1	R_2	R_3	R_4	R_5
MAX. THRUST	1290	0	610	610	576	404	404
LAUNCH 7.25G'S	0	595	−270	−270	−255	−63	−63

Figure A-7

REV

APPENDIX A-I

EQUIPMENT LIST

ALTERNATE RETROGRADE ROCKET SYSTEM

Quantity: Two Day Mission	Quantity: Fourteen Day Mission	Nomenclature	M.A.C. Part No.
4	4	Retrograde Rocket Motors	52-50700

NEW